Ars & Exercitium solent præstare Victoriam.

Veget.

THE

ELEMENTS

OF

FORTIFICATION.

IN TWO VOLUMES.

CONTAINING THE

CONSTRUCTION, ATTACK, *and* DEFENCE

OF

Fortified* PLACES, *Regular and Irregular.

Tranſlated and Collected from the WORKS of the moſt CELEBRATED AUTHORS.

Together with

An Account of MINES, COUNTERMINES, *and of the* ENGINES *and* ARMS *now uſed in* WAR.

To which is prefixed

A Compendious Introductory Treatiſe of GEOMETRY.

VOLUME *the* FIRST.

LONDON:

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To His Royal Highness

WILLIAM AUGUSTUS
DUKE of *CUMBERLAND*,

And Duke *of* Brunswic-Lunenburg, *&c. &c. &c. &c.*
Captain-General of all His Majesty's *Forces*, &c.

May it pleaſe Your Royal Highness,

I Humbly hope that an Attempt towards ſpreading abroad the Knowledge of the Elements of Fortification among the *Britiſh* Soldiery, will in

in ſome meaſure excuſe my Preſumption in laying this Work at Your ROYAL HIGHNESS's Feet.

It is through a ſincere Deſire for the Advancement of this fundamental Branch of Military Science, that I have dared to prefix to theſe Sheets ſo Illuſtrious a Name, which on all occaſions cannot fail to draw the Attention of the Indolent and the Prejudiced, and to render them every way careful in their Endeavours to approve themſelves worthy of fighting under the Banner raiſed for the Support of the Laws and Privileges of the preſent happy Government.

To do Juſtice to the exalted Character of a PRINCE, whoſe heroic Actions, even long before the Noon of Life, ſhine with ſuch Splendor and Glory, muſt only be the Task of a Pen equal thereto; that

when

when the multitudes of Living Teſtimonies, who owe the Continuance of the greateſt Bleſſings to Your ROYAL HIGHNESS's brave and prudent Conduct of His MAJESTY's Forces againſt the wicked Sons of Tyranny and Rebellion, ſhall no longer exiſt, Poſterity may ever gratefully extol thoſe rare Virtues whoſe kind Influences will be felt until the End of Ages. But it becomes ſuch as I am to admire in Silence, being incapable to expreſs the lively Sentiments of a Heart overflowing with the moſt profound Duty and Reſpect; with which I beg leave to profeſs myſelf,

May it pleaſe Your ROYAL HIGHNESS,

Your ROYAL HIGHNESS's

moſt devoted,

and moſt obedient

humble Servant,

J. Rills The EDITOR.

PREFACE.

THE *contents of the following ſheets are collected and tranſlated from the lateſt works of the moſt celebrated authors in* EUROPE, *many of whom are at this preſent time employed in the ſeveral ſchools of artillery abroad, for the inſtruction of the young gentlemen who are called to the profeſſion of arms.*

The Editor had an opportunity for a long while to receive this part of his education among them, before the wars broke out; ſo that he was not in the leaſt expoſed to take up with any diſſatisfactory anſwers to ſuch enquiries that he made concerning military affairs.

The mere intention in the publication of this treatiſe, is for the uſe of the young officers of the army and navy, who from the final paragraph of theſe prefatory lines ought to be convinced, how greatly their employments oblige them to the ſtudy of the Elements of Fortification. *The ſcarcity of books in the* engliſh *language which treat methodically of this art, may be the cauſe that ſeveral young ſoldiers and ſailors, with proper endowments, cannot become acquainted with the true principles of it: Indeed thoſe who have an opportunity of being placed at an academy to receive the inſtructions of able teachers, muſt attribute their future ignorance only to their own incapacities; but how few have ſuch advantageous offers of the great numbers which are in the ſervice!*

PREFACE.

It is generally thought, to the great detriment of the ſervice, that none but ſuch perſons who are deſigned for engineers ought to endeavour to acquire the knowledge of fortifications. The real miſtake is, that a true diſtinction is not made betwixt the knowledge of an officer and that of an engineer, and that perſons ſcarcely qualified are employed in the latter capacity.

The knowledge of the mathematics to a certain degree, without which no true idea can be conceived of any of the liberal arts, *is uſeful to the Stateſman, the Divine, to thoſe of the Law,* &c. *not to mention other profeſſions unto which they are abſolutely neceſſary; in ſhort, every man whoſe vocation requires the leaſt ſpeculation ſhould be careful to obtain, at any rate, ſuch infallible aids.*

The ENGLISH NATION *is, with juſtice, reputed to have produced mathematicians of the firſt rank; their works, both in the* latin *and their native language, are perpetual inſtances of their fame; men of all degrees in theſe* HAPPY ISLANDS *of* LIBERTY *have given ſufficient proofs of the truth of this aſſertion; therefore no one can complain that the road to this moſt uſeful part of ſtudy has not been ſufficiently levelled, or that the way is intricate for want of guides.*

But to come to the diſtinction that is proper to be made betwixt the knowledge requiſite to an officer, and that of an engineer; the former may reſt contented with treaſuring up in his mind the liberal arts, at leaſt thoſe that may prove ſerviceable to him at any critical juncture in the fulfilling of his duty; whereas the engineer muſt not by any means be unacquainted with the mechanical arts, *viz. maſonry, carpentry, ſmiths-work,* &c. *We do not mean only a mere contemplative knowledge, this is included in the former; we muſt ſuppoſe him able truly to underſtand the good and bad qualities of the different materials uſed in the ſeveral trades, and to be capable to diſcern the leaſt faults of any piece of workmanſhip,*

that

that they may be immediately rectified, and hereby prevent any impoſitions or cheats which might probably draw on the ſudden ruin and deſtruction of whatever had been undertaken to be performed.

A treatiſe of fortification is by ſome engineers reckoned imperfect, unleſs the practice of the mechanical arts, with the qualities of the materials, are mentioned in a particular manner therein; but how few are attentive in reading ſo dry a ſubject: And as for thoſe whoſe intereſt requires that they ſhould apply themſelves, ought the mere reading of books to entitle them to the direction of any works, if they want at the ſame time conſtant opportunities of viſiting the maſters and workmen at their daily labour?

M. De Vauban *was eminent, not only for his theory, but for the experience he had gained by the practice of the art. The famous* Coehorn *was his contemporary, and has invented three ſyſtems of fortifications. Theſe two great men were jealous of each other's fame; yet both deſerve the praiſes of poſterity, without entering into any invidious compariſons.*

To give ſome account of the contents of this book, which we have divided into two volumes, in the following manner.

VOLUME the FIRST.

To the elements of fortification we have prefixed a compendious treatiſe of geometry; it was not to be omitted, as theſe ſheets may fall into the hands of numbers who never have had an opportunity of learning the principles of that ſcience, which are previouſly and indiſpenſably neceſſary to the underſtanding of what follows.

An introduction, concerning the definitions, origin, and progreſs of fortifications.

PREFACE.

Chap. I. *The manner how to fortify the body of the place in a regular polygon. The tracing of the plans and profils of the rampart, parapet, foſsè,* &c.

II. *The tracing of the various outworks now practiſed, omitting thoſe which are aboliſhed. The diviſion of the ſtreets and places of arms of a fortreſs, and the ſituation of the public buildings therein; together with a deſcription of the cazerns, powder-magazines, gates, guerites, bridges and drawbridges, batardeaus,* &c. *all whoſe plans and elevations are laid down with ſuch accuracy that the mere inſpection is ſufficient, without much explanation. This chapter concludes with an account of citadels and of ſouterreins.*

III. *The ſecond and third ſyſtems of M.* De Vauban; *the ſecond commonly called the ſyſtem of* Landaw *and* Beffort; *the third is univerſally known to be that of* New-Briſach.

IV. *The ſeveral ſyſtems of fortification of different authors. Thereto is annexed what relates to the ſituation of places, and the manner of tracing a fortreſs upon the ground.*

V. *Of irregular fortification.*

Tables are interſperſed thro' this work for the ſatisfaction of thoſe to whom calculations of trigonometry, &c. *might prove troubleſome; however it muſt be recommended to them to read ſuch treatiſes of the mathematics as can aſſiſt them in their progreſs therein.*

VOLUME

PREFACE.

VOLUME the SECOND.

VI. *An account of mines, countermines, and of the engines and arms now uſed in war; together with the attack of places.*

VII. *Of the defence of places, with proper tables and remarks.*

It will perhaps be of ſome ſignification to give a hint, before we cloſe this preface, of the claſſes into which the engineers of a certain POWER *are judiciouſly divided, for the better ſucceſs of the different enterpriſes and undertakings. Their ſtudies at the ſchools of artillery are general in every ſcience that is neceſſary to be underſtood to make them ſucceed in the practice, not only of military, but likewiſe of civil architecture,* &c.

Moreover, at moſt of the places where theſe ſchools are eſtabliſhed, the converſation of the old engineers and officers of artillery, who have gained experience by their long ſervices, and the daily opportunities of viſiting the fortifications, military edifices, foundery, &c. *with them, haſtens greatly the improvements of the young gentlemen. It is this condeſcenſion in the old warriors that ſtirs up the emulation of the youth; beſides, it is alſo heightened by the conſtant encouragement that they receive from the government; at their leaving the ſchools, they are offered employments in the claſſes according to their capacities and taſte. The conſtruction of the works of fortification is the ſole conſtant buſineſs of ſome; civil architecture, the making of roads, cauſeways, canals, ſluices, docks,* &c. *is the continual practice of others; whilſt a third claſs is only attentive and diligent to gain experience and knowledge in whatever relates to the attack of places; thoſe of another, employ all their skill for the defence of a fortreſs.*

Notwithſtanding the uninterrupted application of each claſs to its own branch, there are many of theſe engineers capable to undertake

dertake ſuch things that can be propoſed to them of any of the claſſes different from their own.

The officers of artillery, viz. *of the gunners, bombardeers, miners, pontoon-men,* &c. *ſhare equal advantages in the ſtudy of their art.*

There was a very ingenious propoſal ſome time ſince of colonel Doxat, *a* German, *to raiſe two regiments, or one regiment of two battalions, whoſe colonel (having the rank of a general officer) ſhould act upon ſervice as engineer in chief; the other officers to be employed as engineers upon enterprizes of more or leſs conſequence, according to their reſpective ranks. Doubtleſs no officer was to be admitted into this regiment without being qualified in every reſpect. All the ſoldiers were to be very able-bodied men, bred up to laborious trades, ſuch as carpenters, ſmiths, bricklayers, maſons, wheel-wrights; alſo labourers uſed to hedging and digging, making of banks,* &c. *and of each of theſe a due proportion. In camp and garriſon theſe regiments were to do duty like others, and the pay was only to become extraordinary to the whole, or to any detachments from them, when they were buſied at any works of fortification.*

How uſeful a ſmall number of theſe might be to intermix with the peaſants and pioneers to forward the work of any intrenchments, lines of circumvallation, &c. *muſt be left for experienced judges to decide.*

Moreover, let it again be argued, whether the aſſiſtance of men brought up in this manner would not be of real ſervice to attend a body of troops, great or ſmall, acting either upon the offenſive or defenſive, by ſea or by land; at home, againſt the invaſions of a declared enemy, or the rebellious proceedings of any ſubjects who have taken up arms againſt their lawful ſovereign; and laſtly, for ſecuring any important conqueſt abroad.

We now conclude, by recommending the ſtudy of this art to all young officers in general; for ſhould not every one entertain the moſt ambitious thoughts, and aſpire to riſe to the higheſt military preferment? And certainly they would be found more worthy of high commands, if they had added to their other ſoldier-like Virtues the art of attacking and defending of places.

" Are there not innumerable opportunities in war, where every " officer is obliged to attack or defend a poſt? Is it to be doubted " but that one who is acquainted with the elementary part of at- " tack and defence, will ſucceed better, and come off with more " honour, than another whoſe ignorance may be attributed to his " own neglect, thinking that mere courage is able to ſerve his " purpoſes in any juncture whatſoever? Will not the former find " ſuch expedients and aſſiſtance that a long experience often miſſes? " If he has an opportunity of being preſent at one ſiege, he will " acquire more skill than if he had been at ſeveral, without " being in a capacity to give an intelligent account of the many " circumſtances that had happened.

" It is in the art of war as in others, wherein theory renders " a man in a very ſhort time fit for practice, in compariſon to " the tedious and frequently uncertain knowledge gained by expe- " rience alone.

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ERRATA.

In the Treatise of Geometry.

Page 6. line 7. for the circumference *of a small number*, read, *of a small circle.*
Page 8. three lines below Fig. 16. in the margin, write Fig. 17.
Page 32. dele Fig. 70. three lines below Fig. 69. in the margin.

In the Geometry Plates.

Plate 4. write Fig. 64. instead of 60. to the parallelogram with the diagonal B C.
Plate 5. Fig. 90. write C at the top of the right angle subtended by the hypothenuse A B.
Fig. 100. write Q betwixt D, C, of the truncated cone.

In the Elements of Fortification.

Page 11. line 19. for B I K, read H I K, *the angle of the flanc.*
Page 96. line 10. for, *but only added to half the angle of the polygon*, read, *but only added to the angle* N A C.
line 11. dele *on each side.*
Page 157. line 16. after *nine feet* put a *full-stop.*
line 17. instead of a *full-stop* put a *comma.*
Page 179. line 5. for *fortify within*, read *fortify without.*

A

COMPENDIOUS INTRODUCTORY

TREATISE

OF

GEOMETRY.

A

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A COMPENDIOUS INTRODUCTORY

TREATISE

OF

*GEOMETRY.

I.

GEOMETRY is a ſcience that conſiders the properties of *extenſion.*

That which has *length*, *breadth*, and *depth*, is called *extenſion.*

Extenſion may be conſidered either with theſe three dimenſions, or with two, or with one only.

Extenſion, conſidered as length, without any breadth or depth, is called a *line.* Fig. 1.

Extenſion, conſidered with breadth and length, is called *ſurface*, or *ſuperficies*, as A B C D. Fig. 3.

Extenſion, conſidered with the three dimenſions, *viz.* with length, breadth, and depth, is called a *body*, or a *ſolid.* Fig. 5.

Although there is neither extenſion nor body without the three dimenſions, we may nevertheleſs conſider each dimenſion by itſelf. For inſtance, when we ſpeak of the diſtance of one place from another, as from *London* to

* This treatiſe is compiled for the uſe of beginners; it contains merely ſuch principles as are previouſly neceſſary to the ſtudy of fortification.

York, we do not conſider breadth in this diſtance, but only the length which is between theſe two towns. So in ſpeaking of a looking-glaſs, which is ſaid to be four or five feet high, and three broad, no notice is taken of its thickneſs, but only of its ſuperficies, and in the ſame manner when we ſpeak of the extent of a field or a garden, *&c.* Laſtly, if we conſider the maſs of any thing, as of lead or marble, *&c.* we then take notice of its length, breadth, and depth, that is, we conſider it with the three dimenſions.

A mathematical point is imagined without any dimenſion, it only marks a place in extenſion.

In order to have a right notion of a mathematical point, we muſt imagine two lines mutually interſecting one another; the place of their interſection can have neither breadth nor depth, ſince the lines themſelves have none; neither can it have any length, unleſs it be in the direction of both lines, which is impoſſible, for then it would have breadth. Therefore the place where theſe two lines interſect one another is a point or place which has neither length, breadth, nor thickneſs. The *extremities* of lines are alſo mathematical points, for the extremity of a line cannot be ſaid to have breadth, becauſe the line has none; nor can it have any length, becauſe it would then be a line itſelf, and not the extremity of a line. Therefore, *&c.*

Lines are either *right*, or *curve*.

Fig. 1. A *right line* is the ſhorteſt that can be drawn from one point to another, as the line A B. Its ſituation depends on the two points A and B, which being given determine the right line.

Fig. 2. A *curve line* is not the ſhorteſt that can be drawn from one point to another; and therefore the two points C and D being given, do not determine the curve.

Two

Two right lines can interſect one another only in one point.

A ſuperficies is either *flat*, or *curve*.

A flat ſuperficies is called a *plane*. Fig. 3.

A curve ſuperficies is *convex* on one ſide, and *concave* on the other. Fig. 4.

A ſuperficies terminated on all ſides by lines is called a *plane figure*. Fig. 3.

A body terminated on all ſides with ſurfaces is called a *ſolid figure*. Fig. 5.

II. *Of the circle.*

A *circle* is a plane figure terminated by a curve line, whoſe points are equally diſtant from a point in the figure, called the *center*. Such is the figure terminated by the curve line AEBDA, whoſe center is C. Fig. 6.

The curve line which terminates the circle is called the *circumference*; ſo the curve line AEDA is the circumference of the circle, whoſe center is C.

A part of the circumference is called an *arch*, and the right line drawn from the extremities of the arch is called its *chord*.

So ABD being an arch, the right line AD will be its chord. Fig. 7.

A right line, as the line AB, which is drawn through the center C of a circle, and terminated on both ſides by the circumference, is called a *diameter*. Fig. 8.

And a right line, as CD, drawn from the center C of a circle to its circumference, is called *ſemidiameter* or *radius*.

It follows from the definition of a circle, that in a circle or in equal circles, the radius's are equal as well as the diameters.

The

The diameter cuts the circle and its circumference into two equal parts.

Geometricians divide the circumference of the circle into 360 equal parts, which are called *degrees*, and each degree into 60 equal parts called *minutes*, and each minute into 60 *ſeconds*, &c.

The circumference of a ſmall number being divided into the ſame number of degrees as that of a large circle, the degrees of the latter will be greater, and conſequently a degree is but a relative meaſure.

Fig. 8. The right line E F, which touches the circumference of a circle in a point only, and being continued both ways from that point does not at all cut the circumference, is called a *tangent*.

PROBLEMS.

Fig. 9. 1. *To deſcribe a circle with a given line* A B *for the radius.*

Take a pair of compaſſes, fix one of its feet on the point A of the given line, and open it till the other foot falls on the point B, and keeping the firſt foot fixed on the point A, move the other round the point A, and it will deſcribe the circle required.

Fig. 10. 2. *Two points* A *and* B *being given upon a plane, to find a line* C D, *having all its parts equally diſtant from theſe two parts.*

As the ſituation of a right line depends on the poſition of two points, it follows, that if you find the two points C and D equally diſtant from A and B, the line paſſing through theſe two points will be the line required.

From the points A and B taken as centers, and with any interval, deſcribe above and under the given points two arches

arches cutting one another in C and in D, and draw through theſe points the line C D, all its parts will be equally diſtant from A and B. For the lines A D, B D, are equal, and alſo the lines A C, B C, being radius's of equal circles. Therefore, *&c.*

3. *To divide a line* A B *into two equal parts.* Fig. 11.

Find a line C D, with all its parts equally diſtant from the points A B, the extremities of the line A B, and the point M where the line C D cuts the given Line will be the middle of it.

4. *To divide an arch* A B *into two equal parts.* Fig. 12.

Draw the line C D, with all its parts equally diſtant from the extremities A and B of the given arch; this line will cut it in the point M, which will be the middle of it.

5. *To deſcribe the circumference of a circle through three given points,* 1, 2, 3, *which are not placed in a right line.* Fig. 13.

Find the line E D, with all its parts equally diſtant from the points 1 and 2; and then a ſecond line A B, having likewiſe all its parts equally diſtant from the points 2 and 3; the point C, where theſe two lines interſect one another, will be the center of the circle required; ſo that taking the points C for a center, and deſcribing a circle with the diſtance from C to one of the given points, its circumference will paſs through the other points.

For the line A B having all its parts equally diſtant from the two points 2 and 3, the point C of this line will be alſo equally diſtant from them; but the ſame point C belongs likewiſe to the line E D, which has all its parts equally diſtant from the two points 1 and 2; therefore the point C is equally diſtant from the three given points. Therefore, *&c.*

The

The center of a circle, or of a given arch, may be found alſo after the ſame manner, by marking three points in the circumference or given arch, and then finding the center of the circumference which paſſes through theſe three points, as in the foregoing problem.

III. *Of an angle.*

Fig. 14. An *Angle* is the opening of any two lines, as A B, B C, meeting in the point B.

The lines A B, B C, are called the *legs* or *ſides* of the angle; and the point B, where they meet, the *vertex* or *top* of the angle.

An angle is commonly denoted by three letters, of which the middle one denotes the vertex; thus this angle is called A B C, or C B A.

An angle is greater or leſs in proportion to the opening of its legs, but the length of the legs alters nothing as to the meaſure of an angle.

The lines which make an angle may be either right or curve.

The angle A B C, which has two right lines, is called
Fig. 14. *rectilinear*, or right-lined angle; the angle D E F, compre-
Fig. 15. hended by curve lines, is called *curvilinear*; and the angle G H I, made by one right line and one curved one, is
Fig. 16. called a *mixtilinear angle.*

We ſhall treat only of the *rectilinear* angle.

The angle A B C is meaſured by the arch A C of a circle, which is intercepted between the legs of the angle, whoſe center is the vertex B of the angle, and which is drawn from thence with any given diſtance.

Wherefore an angle is meaſured by degrees, and as the circumference of a ſmall circle has as many degrees as that of a great one, the arch by which the angle is to be meaſured

meaſured may be drawn at any diſtance from the center, ſince all the arches which may be intercepted between the legs of the angle will have an equal number of degrees.

An angle is differently named, according to its meaſure.

An angle, as A B C, whoſe meaſure is a fourth part of the circumference, or 90 degrees, is called a *right angle.* Fig. 18.

An angle whoſe arch contains leſs than 90 degrees, as the angle D E F, is called an *acute angle*; and an angle whoſe arch is greater than the fourth part of the circumference, as the angle G H L, is called an *obtuſe angle.* Fig. 19. Fig. 20.

An obtuſe angle may be increaſed till the ſemi-circumference, or 180 degrees, is the meaſure of it; but then there is no angle, and its two ſides make a right line.

If from the point C in the line A B, ſeveral lines D C, E C, *&c.* are drawn, all the angles which theſe lines will make, with the line A B, will be equal to two right ones. For if from the point C, taken as a center, and at any diſtance, a ſemi-circle is deſcribed upon the line A B, all the angles whoſe heads are at the point C will be meaſured by that circumference; but the half of that circumference is the meaſure of two right angles. Therefore, *&c.* Fig. 21.

Angles thus made on the ſame line are called *contiguous angles*, and angles oppoſite at their heads by the interſection of two lines are *equal.*

Let there be two lines A B, C D, cutting one another in the point E, the angles C E B, A E D, are ſaid to be vertically oppoſite as well as the angles A E C, D E B, and we are to prove that theſe angles are equal. Fig. 22.

We have juſt ſeen, that the contiguous angles A E C and C E B are equal to two right angles, as well as the two contiguous angles C E A and A E D.

Therefore, if from the two angles made on the line AB the angle AEC is taken off, there will remain the angle CEB; and if from the two angles made upon the line CD the ſame angle AEC is taken off; there will remain the angle AED equal to the oppoſite angle CEB, ſince in adding to each of them the angle AEC, they are equal to two right angles. We may demonſtrate after the ſame manner, that the two angles AEC, DEB, are equal.

PROBLEMS.

Fig. 23. 1. *Upon a given line* AB *to make an angle equal to a given angle* KEL.

From the vertex E of the given angle taken as center, and with an interval EG taken at pleaſure, deſcribe an arch GH between its ſides; and from the point A taken as center, upon the given line AB, and with the ſame interval EG, deſcribe an indefinite arch, on which you will take the arch CD, equal to the arch GH. Draw then the line AD, and the angle DAC will be equal to the angle GEH.

Fig. 24. 2. *To cut an angle* ABC *into two equal parts.*

From the vertex B of the given angle, taken as center, and with an interval taken at pleaſure, deſcribe an arch EF between its ſides, then divide the chord of this arch into two equal parts by the line BD, and the given angle ABC will be alſo cut into two equal parts.

3. *Upon a given line to make an angle of any number of degrees whatever.*

To ſolve this problem, make uſe of the inſtrument called *protractor*, which is nothing elſe but a ſemi-circle either of braſs or of horn, divided into degrees and half degrees.

To

To make an angle of any number of degrees whatever with this inſtrument, place its diameter upon the given line in ſuch a manner that its center anſwers to the point where the vertex of the angle is intended; reckon then upon its circumference the number of degrees required; mark a point upon the paper or plane in the place which anſwers to the extremity of thoſe degrees, and deſcribing a line through this point and that upon which the diameter of the protractor has been placed, you will have the angle required.

One may alſo in the ſame manner, with the protractor, find the number of degrees of a given angle.

IV. *Of perpendicular, oblique, and parallel lines.*

A line is perpendicular to another line when it makes, with that line, two right angles; or, which is the ſame thing, when it does not incline upon that line more to one ſide than to the other. Fig. 25.

So if the line D C does not incline upon the line A B more to the ſide A than to the ſide B, it will be perpendicular to A B, and this will alſo be perpendicular upon C D.

A line is oblique to another line when it makes unequal angles with it; or, which is the ſame thing, when it inclines upon it more to one ſide than to the other. Thus the line H G inclining more towards B than towards A, upon the line A B, is oblique to that line. Fig. 26.

If two points C and D of a right line, are equally diſtant from two points A and B of another right line, I ſay that the firſt is perpendicular to the ſecond. Fig. 25.

For the ſituation of a right line depends on two points, therefore by the ſuppoſition the point C and the point D

are both equally diſtant from the two points A and B; therefore all the parts of the line C D are equally diſtant from the two ſame points; therefore it does not incline more on one ſide than on the other upon A B, therefore it is perpendicular to this line.

Fig. 27. If from a point C, out of a line A B, a perpendicular C D and the oblique lines C E, C F, C G, are drawn upon the line A B, the perpendicular C D is the ſhorteſt; the oblique lines C E, C F, falling upon the line A B in the points E and F, equally diſtant from the extremity D of the perpendicular, will be equal; and the line C G, meeting the line A B in the point the moſt diſtant from the point D, will be the longeſt.

In order to prove firſt, that the perpendicular line C D is the ſhorteſt, produce that line to H, and make D H equal to C D; then draw the lines H E, H F, the lines C E, C F, will be each the half of the lines C E H, C F H; for the line A B being perpendicular to the line C H, and the points C and H being both equally diſtant from the point D, by the ſuppoſition it follows that all the points of the line A B will be equally diſtant from the two points C and D, and conſequently that the lines C E, E H, C F, F H, that meaſure equal diſtances, will be equal; therefore the lines C E, C F, will be each the half of the lines C E H, C F H; but the right line C H is ſhorter than the lines C E H, C F H, which are not right lines; therefore the half of it C D will be likewiſe ſhorter than C E, C F, the halves of the lines C E H, C F H. Therefore, *&c.*

To prove the ſecond caſe, we muſt conſider that the points E and F being both equally diſtant from the point D and the point C, it appears evidently that the lines C E, C F, are equal.

To

To prove the third caſe, namely, that the line G G is longer than the line C F: draw the line G H to have the line C G H, the half of which will be the line C G; therefore the line C G H, which contains the line C F H, will be longer than this line; therefore the half of it, C G, will be likewiſe longer than C F, which is the half of the line C F H. Therefore, *&c.*

The inclination of a line C E may be meaſured either by its diſtance D E from the perpendicular C D, drawn from its extremity C upon the line A B, or by the angle C E B which that line makes with the line A B. But we have juſt ſeen, that the oblique lines C E, C F, which fall upon the line A B in the points E and F, equally diſtant from the point D, are equal; therefore when two oblique lines are equal upon the ſame line, and have a point common to both, we may conclude that the other extremity of them both will be equally diſtant from the perpendicular drawn from their common point upon the line where they are oblique, or that the angles which they make with that line will be equal, and *vice verſâ*, when theſe angles are equal, and the oblique lines C E, C F, meet in the ſame point C, we may conclude that theſe lines are equal. Fig. 27.

It follows from this propoſition, that the perpendicular line is the ſhorteſt that can be drawn from a point out of a line upon that line; and conſequently that it meaſures the diſtance from it.

A line A B is parallel to another line C D, when all its parts are equally diſtant from it. Fig. 28.

This diſtance is meaſured by the perpendicular lines E F, G H, drawn between the parallel lines, and conſequently all theſe perpendicular lines are equal.

If two parallel lines fall upon a right line, the angles which they make on the ſame ſide with this line are equal.

Let

Fig. 29. Let there be two parallel lines CD, EF, falling upon the line AB, I ſay that the angles CDA, EFA, are equal.

This will appear clearly by obſerving, that if theſe angles were unequal, the lines CD, EF, would come nearer at one end than at the other, and conſequently would not be parallel, which is againſt the ſuppoſition.

The angle CDA, which is without the parallel, is called *external*; and the other, EFA, which is equal, is called its *oppoſite internal.*

Fig. 30. When a right line, as EF, cuts two parallel lines, it makes eight angles; four of which are externals, or without the parallels; and four internals, or within the parallels: among the internals, the angles AHF, DGE, are called *alternates*, and thoſe angles are always equal.

In order to prove this it is to be obſerved, that we have juſt now demonſtrated that the external angle EHB is equal to its oppoſite internal one EGD; but the external angle EHB is equal alſo to the angle AHF, becauſe it is vertically oppoſite to it; therefore the alternate angles AHF, EGD, are equal, ſince they are each of them equal to the ſame angle EHB.

PROBLEMS.

Fig. 31. 1. *From a given point* C, *to raiſe a perpendicular upon a line.*

Mark two points A and B, equidiſtant from the point C; and from the points A and B, taken for centers, and with an interval taken at will, deſcribe two arches that cut themſelves in a point D; the line drawn from the point C to the point D will be perpendicular to the line AB; for by the conſtruction, the points C and D

are

are each of them equidiſtant from the points A and B. Therefore, &c.

2. *From a given point* C *out of a line* GH, *to draw a perpendicular to that line.* Fig. 32.

From a point C taken for a center, deſcribe an arch that cuts the line GH in any two points A and B; and from the ſame points, taken alſo for the centers, and with an interval taken at will, deſcribe two arches under the line GH that cut one another at a point D; from the point D and from the point C draw the line CD until it meets GH at the point E, and the line CE will be perpendicular to GH.

3. *From a given point at the extremity of a line, to raiſe a perpendicular.*

Lengthen the given line on the ſide where you raiſe your perpendicular, and then go on as in the firſt problem.

4. *Through a given point* A *out of a line* CD, *to draw a parallel thereto.* Fig. 33.

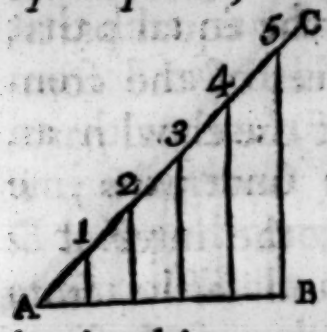
From the point C, taken as a center and at will, upon the given line CD, and with the diſtance CA, draw an arch that cuts CD in E; and from the point A, taken as a center, and with the ſame interval CA deſcribe another arch CB at the point C; then make the arch CB equal to the arch AE, and draw the line AB it will be parallel to CD; for by drawing the line CA, the alternate angles ACD, CAB, are equal by the conſtruction; therefore the lines BA, CD, are parallel.

5. *To draw a line parallel to a given line* AB. Fig. 34.

Take two points upon the line AB, that is, near each extremity A and B, and from each of theſe points, taken for centers, deſcribe two arches, with a radius equal to the diſtance there ſhould be between the parallels; then draw

a line C D that touches theſe two arches without cutting them, and it will be parallel to the line A B.

6. *To divide a right line* A B *into any given number of equal parts*; ex. gr. *five.*



Draw from the extreme point A a line A C, that forms at will with A B an angle C A B; upon A C carry the compaſſes A 1, beginning from the point A, which is taken at will alſo juſt as many times as the line A B has equal parts, that is, in this example five times; thro' the point 5 and thro' the point B draw the line 5 B, and at each of the points 1, 2, 3, *&c.* draw the parallels to the line 5 B, ſo that they may cut the line A B, and they will divide that line into five equal parts.

In order to prove it, conſider that by the conſtruction the line A 5 is divided into five equal parts; that all thoſe parts are each of them equally inclined between the parallels to the line 5 B, and alſo that the ſpaces that are between two of theſe parallels are equal. Now all the five parts into which A B is divided are likewiſe equally inclined in the ſame parallel equal ſpaces; therefore they are all equal.

The *ſector*, which is an inſtrument made of two braſs rules joined together, and that move about a common center, ſhews a way how to divide a line very eaſily into many equal parts.

You find upon that inſtrument two lines, each of which is marked with *equal parts*. Each of thoſe lines is divided into 100, or 120, or 200 equal parts.

In order to divide a line into many equal parts with the ſector, for inſtance, into five, take with the compaſſes the length of the given line, and with the compaſſes thus open,

ſet

ſet one of its feet at one of the numbers of the line of the equal parts, which may be divided exactly and without any remainder by 5, as upon 50, 100, or 120, &c. open the ſector until the other foot of the compaſſes falls upon the ſame number of the other line of the equal parts; the ſector remaining thus opened, if the feet of the compaſſes are ſet on the numbers 50 and 50 of the equal parts, the interval is taken from 10 to 10 of the ſame parts; if they are ſet on the numbers 100 and 100, the interval is taken from 20 to 20 of the ſame parts; and laſtly, from 24 to 24, if they are ſet on 120 to 120, any of theſe intervals will be the fifth part of the given line; and if it is carried upon that line, it will divide it into five equal parts. The ſame method may be made uſe of to divide a given line into a greater number of equal parts.

If the given line is too great to be taken with the compaſſes and carried upon the ſector, we muſt then divide it at pleaſure into many parts, and take the fifth of each of theſe parts if we are willing to divide the line into five equal parts. It is evident that all the five parts of each of theſe firſt parts taken together, will give the fifth part of the given line.

V. *Of triangles.*

It has been already ſaid, that a *figure* was a ſpace or ſurface bounded on all ſides by lines.

A figure terminated on all ſides by right lines is called a *rectilinear* figure; a figure terminated by curved lines is called *curvilinear*; and *mixtilinear*, if it is bounded by right and curved lines.

In common geometry, no figure that is curvilinear or mixtilinear is conſidered, unleſs it is the circle or the parts of it.

Among the figures that are rectilinear, the moſt ſimple are the triangles, which are made by three right lines, as
Fig. 35. the triangle ABC made by the lines AB, BC, CA.

Triangles have different names juſt as they are conſidered, both as to their ſides and angles.

A triangle ABC, whoſe three ſides are equal, is called an *equilateral* triangle; that whoſe two ſides are equal, as
Fig. 36. the triangle A, is called an *iſoſceles*; and that whoſe three ſides are unequal, as the triangle ABC, is called a
Fig. 37. *ſcalene*.

A triangle that has a right angle ABC, is called a
Fig. 38. *rectangle* triangle; and the ſide AC of the rectangle triangle, oppoſite to the right angle, is called the *hypothenuſe*.

A triangle which has an angle ACB obtuſe, is called
Fig. 37. an *obtuſe* angle, or *ambligon*; and that whoſe three ſides is acute is called an *acute* angle, or *oxygon*.

Fig. 35. One of the ſides taken at will is called the *baſe* of a triangle, and then the top of the angle oppoſite to that ſide is called *the top or vertex of the triangle*.

Fig. 39. The ſides CA, CB, of a triangle are fixed by the angles which they make with its baſe; *i. e.* that the ſides are equal, if the angles of the baſe CAB, CBA, are equal; and that they are unequal, if theſe angles are unequal. For if the angles of the baſe of the triangle ABC are equal, the ſides CA, CB, will be equally inclined, and conſequently equal. But if thoſe angles are unequal, the ſides CA, CB, will be unequally inclined, and then they will be unequal.

Hence it follows, that the equilateral triangle has its three angles equal, the iſoſceles triangle two angles equal, and the ſcalene triangle its three angles unequal.

The three angles of every triangle, taken together, are equal to two right angles, or to 180 degrees.

In

In order to prove it, at the top C of the triangle A B C, let D C E be drawn parallel to its baſe A B; the three angles D C A, A C B, B C E, will be together equal to two right angles; ſo that if it be ſhewn that thoſe three angles are equal to the three angles of the triangle A B C, it may be concluded from thence that the three angles of that triangle are equal to two right angles. Now becauſe of the parallel D E the angle A B C is equal to the angle B C E, becauſe they are alternate; and for the ſame reaſon the angle B A C is equal to the angle A C D; the angle A C D is the third angle of the triangle, therefore the three contiguous angles at the point C are equal to the three angles of the triangle. Therefore, *&c.* Fig. 39.

Whence it follows, that if one of the ſides A C of a triangle be lengthened out, the exterior angle B C D will be equal to the two angles at the baſe of the triangle. Fig. 40.

And that if two angles of a triangle are known, the other alſo will be known; this being done only by ſubſtracting the ſum of the two known angles from 180 degrees, and the remainder will give the number of degrees of the third angle of the triangle.

If a triangle A B C has its three ſides equal to the three ſides of another triangle *a b c*, the firſt triangle will be equal to the ſecond. For if you lay the three ſides of the former triangle upon the three ſides of the latter, their extremities will fall upon one another, becauſe theſe ſides are ſuppoſed to be equal, and conſequently theſe two triangles will perfectly coincide and agree together. Therefore they are equal. Fig. 41.

If two ſides, C A, C B, of a triangle be equal to two ſides *c a*, *c b*, of another triangle, and if the angle made by thoſe two ſides be equal in both triangles, theſe two triangles will be equal. For if you lay the ſide A C of the Fig. 42.

one on the ſide *a c* of the other, they will coincide exactly; and becauſe the angles A C B, *a c b*, are equal, the ſide C B will fall on the ſide *c b*, and the extremities A and B will fall on the extremities *a* and *b*; therefore the baſe A B will be equal to the baſe *a b*; therefore the triangle A B C will be equal to the triangle *a b c*.

Fig. 43. If the baſe A B of a triangle A B C be equal to the baſe *a b* of another triangle *a b c*, and if the angles at the baſe of the former triangle be equal to the angles at the baſe of the other, theſe two triangles will be equal. For if you lay the baſe A B upon the baſe *a b*, their extremities will fall in with one another, becauſe theſe two lines are ſuppoſed to be equal; and the angles at the baſes of each triangle being equal, the ſide A C will fall upon the ſide *a c*, and the ſide B C upon the ſide *b c*; ſo that theſe two lines will meet at the point C; therefore theſe two triangles will mutually agree in all points, and conſequently be equal.

In every triangle two ſides taken together are greater than the third; for, take any one of the ſides, for inſtance A B, as it is a right line, it will be the ſhorteſt that can be drawn between two points, and therefore B C, C A, taken together which do not form a right line, muſt be greater.

PROBLEMS.

Fig. 44. 1. *To make an equilateral triangle upon a given line.*

Taking the extreme points A and B for centers, with an extent of this line, deſcribe two arches cutting one another in the point C, then draw the line C A, C B, which will give you the equilateral triangle A B C.

Fig. 45. 2. *To make a triangle of three given lines* A, B, C, *two of which taken together are greater than the third.*

Take

Take one of the given ſides A for a baſe, and from one of its extremities, taken as a center, and with the extent of the line B, deſcribe an arch; from the other extremity of the line A, and with the extent of the line C, deſcribe another arch cutting the former in the point D, from whence draw the lines to the extremities of the baſe A, and you will have the triangle A B C, whoſe ſides will be the three given lines A B C.

3. *To make a triangle upon a given line* A B, *whoſe angles at the baſe ſhall be equal to the given angles* C *and* D, *and which are ſuppoſed to be leſs than two right angles.* Fig. 46.

At the extremities A and B of the ſide A B, make two angles equal to the given one C and D; the legs of theſe angles will cut one another in C, which will be the top of the triangle required.

Uſes that may be made of triangles for meaſuring inacceſſible lines, or thoſe acceſſible at their extremities only.

That part of geometry which teaches the uſe of triangles, and the method of finding their unknown ſides and angles, by means of their ſides and angles that are known, is called *trigonometry*. Problems of this ſort may be ſolved either by trigonometrical calculations, or without them. The former way is the moſt accurate and exact; but as it previouſly requires a knowledge of things that there will be no need to treat of here, the following problems ſhall be ſolved without them.

1. *To find the length* A B *of a lake, or which is the ſame thing, of a line, which is acceſſible only at its two extremities* A *and* B. Fig. 47.

If the country be ſo open as to give you room enough to act in the following manner, chooſe any point C at will from

from whence you may ſee the points A and B; fix a ſtaff or piquet at C, and retire from thence in the direction CB until you make CE equal to it; retire likewiſe from the ſame point C in the direction of AC, until CD be equal to it; then meaſure the line DE, which will be equal to the line AB. For the triangle DCE is equal to the triangle ACB, becauſe its two ſides CD and CE are equal to the two ſides CB and CA of the triangle ACB, the angles DCE and ACB contained between theſe ſides being alſo equal, for they are oppoſite at their top. Therefore, *&c.*

But if you have not room to make a triangle DCE equal to a triangle ACB, you may find the length of the
Fig. 49. line AB by making a triangle *a c b*, like or ſimilar to the triangle ACB, which is done by means of a *ſcale* and a protractor.

Fig. 48. The *ſcale* of a plan or figure is a right line divided into a certain number of parts, to which you give ſuch length and denomination as you pleaſe. It ſerves to increaſe or leſſen a figure according as its parts are greater or leſs, without altering the proportion the lines of the figure have to one another.

Fig. 47. As for example; in order to make a draught upon paper of the triangle ACB, the ſides CA, CB, and the angle alſo ACB, which they contain, muſt be meaſured, that is, the three things which determine a triangle, muſt firſt be known; then a ſcale is to be made, which is done in
Fig. 48. the following manner. Draw an indefinite right line AB, and take a ſmall part of it AC at pleaſure, which you may call one or ten fathoms, *&c.* If you are to draw a figure that is to be meaſured by fathoms, then lay this part AC a certain number of times upon the line AB, ſo that this line may contain a number of fathoms nearly equal to the

the longeſt ſide of the figure; this will make it fitter for practice; but this precaution is not abſolutely neceſſary, becauſe a ſcale may be greater or leſs without much inconveniency. At each diviſion of the ſcale, write underneath the number of fathoms which it contains, beginning at the point A, and the laſt number wrote under the point B will expreſs the length of the whole ſcale.

Let us ſuppoſe, at preſent, that the ſide A C of the triangle A C B is found to be 40 fathoms, and the ſide C B 30, and that the angle A C B is 50 degrees; draw the indefinite line *a c*, and take 40 fathoms on the ſcale which lay on this line from *a* to *c*; make at the point *c* an angle *a c b* of 50 degrees with the protractor, and taking 30 fathoms on the ſcale, lay them on the ſide *c b* from *c* to *b*, and draw the line *a b*, which being applied to the ſcale will ſhew the number of fathoms it contains, *i. e.* thoſe which the line A B of *fig.* 47, contains on the ground; for every fathom of the ſcale ſhews every fathom on the ground, and the triangle *a c b* is determined in the ſame manner as, or made ſimilar to the triangle A C B; therefore the number of fathoms of the line *a b* belonging to the triangle *a b c* will be equal to that of the line A B belonging to the triangle A B C. Fig. 47. Fig. 48. Fig. 49. Fig. 49. Fig. 47. Fig. 49.

Two figures thus agreeing in all circumſtances except in meaſure are called *ſimilar figures*.

Whence it follows, that two triangles are ſimilar when the angles of the one are equal to the angles of the other reſpectively, and their ſides being divided into the ſame number of equal parts, may, as to their magnitude, differ in one triangle from thoſe in the other.

Homologous ſides in ſimilar figures are thoſe that are oppoſite to equal angles in each figure; thus in two ſimilar rectangle triangles the hypothenuſes are *homologous* ſides.

The

The proportion that is between two homologous ſides, or two ſimilar figures, is the ſame as is between all the homologous ſides of thoſe two figures. Wherefore, if there be two ſimilar triangles, and if two ſides of the one be known, and a ſide homologous with one of theſe ſides in the other, you may find by the *rule of three* the two other ſides of this latter. An example of this ſhall be given in the ſeries of the following problems.

Angles are meaſured in a field almoſt in the ſame manner as on paper, by means of a copper or wooden ſemi-
Fig. 50. circle G I D, raiſed on a ſtaff, on which it is made to move about by means of a ball and ſocket.

This ſemi-circle is divided, like the protractor, into degrees, half degrees, quarter degrees, and even into leſſer parts, becauſe it is a larger inſtrument. At the extreme points G and D of its diameter, there are two little parallel plates that are perpendicular to the diameter, and drill'd thro' in ſuch a manner, that the viſual ray which comes thro' their two orifices may paſs thro' the center of the inſtrument; theſe plates are called *vanes* or *ſights*. This ſemi-circle has a rule called an *alhidade*, belonging to it, made moveable about its center C, on the extremities of which there are two *vanes* drilled thro' in the ſame manner, and with the ſame caution as the former.

In order to meaſure an angle with this inſtrument, for
Fig. 47. inſtance, the angle A C B, you muſt place the center of the inſtrument over the point C, directing the diameter of the ſemi-circle in ſuch a manner as that you may ſee the point A by looking thro' the vanes G and D. While the inſtrument remains in this ſituation, turn the moveable rule H I gently towards B, until you can ſee that point thro' the vanes of the rule. In this caſe the diameter of the ſemi-circle, and its moveable rule, will be in the ſide C A

and

and C B of the angle A C B, and its center C at the top of the ſaid angle. Therefore reckoning the degrees of the arch contained between the ſides A C and C B, you will have the quantity of the angle A C B.

You muſt take care to direct the ſemi-circle in ſuch a manner, as that its circumference be always between the ſides of the angle that is to be meaſured.

2. *To meaſure the breadth of a river.* Fig. 51.

You muſt take the length of the line A B on one ſide of the river, and obſerve a point C on the other; then imagine the two lines A C, B C, in order to have a triangle A B C. Take the meaſure of the angles C A B and C B A; thus in the triangle A B C you will have the baſe A B, and the angles at the baſe; that is, three things which will give you the triangle; for if you draw it upon paper, you will find the ſide A C, that is, the breadth of the river.

3. *To find the diſtance* C *and* D *of two places you cannot come at.* Fig. 52.

Take the length of a line A B in the field, as in the foregoing problem, and if you make a triangle *a b c* ſimilar to the triangle A B C by means of a ſcale, you will then have a point *c*. In the ſame manner make a triangle *a b d* ſimilar to the triangle A B D, and then you will have the points *c* and *d*; ſo that laying the diſtance *c d* on the ſcale, you will find the number of fathoms for the diſtance of the two places C and D in the country.

4. *To find the height* A C *of a tower or of a line*, &c. Fig. 53. *acceſſible at the botttom* A.

Take the meaſure of a line A B from the foot of the tower A of any length, but nearly equal to the height of the tower, if the ground will permit it; at the end B of this line place your ſemi-circle in ſuch a manner, as that its circum-

ference ſhall be in a vertical ſituation, or perpendicular to the ground, and its diameter parallel to it; this being done, take the meaſure of the angle EDC, by moving the rule of the ſemi-circle until you can ſee the point C through its vanes, and as the angle CED or CAB is a right one, all buildings being raiſed perpendicular to the horizon, it follows, that you have the three things requiſite for finding the triangle CDE, *viz.* one ſide ED, and the two angles on that ſide; wherefore by making of a ſimilar triangle, as in the foregoing problems, you will know the length of the line CE, to which if you add the line EA or DB, that is, the height of the inſtrument, you will have the height AC.

Fig. 54. 5. *To meaſure the height* CD *of a tower inacceſſible.*

Meaſure a line AB in the field, from the ends of which A and B you may ſee the point C; place your inſtrument at the point A in a vertical ſituation, as in the foregoing problem, and imagine the lines EC and CF drawn in the air; then meaſure the angle CFE by moving the rule until you can ſee the point C through its vanes; then remove your inſtrument to the point B, and place it in the ſame ſituation as it was at the point A; but care muſt be taken that its diameter be ſtill in the line EF or AB; then meaſure the angle CEG, or the angle CEF, and draw the triangle CEF upon paper, whoſe baſe EF is known, as alſo its angles at the baſe CEF and CFE, you will then have the point C determined by means of this triangle; and in order to get the height CG, you muſt let fall a perpendicular CD from the point C upon the baſe FE, continued from the point E, until it cuts the perpendicular CD at the point G; this perpendicular CG being meaſured on the ſcale, will give you its length in fathoms, to which if you add the height FA or GD

of

of the inſtrument, you will have the height of the inacceſſible line CD.

6. *To find the height of a line* AB *acceſſible only at the bottom* A, *without an inſtrument.* Fig. 55.

Take two ſticks DE, CF, of different lengths, and fix one of them DE in the ground, at any diſtance AD from the extreme point A of the line AB; then fix the other ſtick FC in a point C of the line AD continued; this point is had by bringing the three points F, E, B, in one line, which is done by looking on the point B through the points F and C; theſe ſticks being thus fixed perpendicularly, imagine a line FH to be drawn parallel to CA, which will make two ſimilar triangles FGE, FHB, for GE is perpendicular to AC as well as HB, therefore theſe two lines are parallel; therefore the exterior angle EGF will be equal to its oppoſite interior BHF, as alſo the angle GEF to the angle HBF; therefore the three angles of the little triangle FGE will be equal to the three angles of the great triangle FHB, reſpectively one to another; therefore theſe two triangles are ſimilar. Wherefore by meaſuring the ſides GF, GE, in the little triangle, and the ſide FH in the great one, which is homologous to the ſide FG of the little triangle FGE, you will find the length of BH, which is homologous to the ſide GE, by means of the *rule of three*; for inſtance, ſuppoſe the diſtance FG be 12 foot, and GE which is the difference of the two ſtaffs be nine foot, and laſtly, FH or CA be 50 foot, BH will be found, by ſaying, if CD (12) give CA (50), what will GE (9) give? anſwer, 37 foot 6 inches, the length of the line BH; to which you muſt add CF or HA, the height of the ſtick CF, to have the whole height AB.

7. To make a ſurvey, i. e. *a draught or map of a country.*

A draught or map is a plain figure, in which all the places of a country are ſet down according to the ſituation they have in reſpect to one another. It is properly a figure ſimilar to that of the country, and on which the diſtances of places are known by means of a ſcale. It is not neceſſary to go through all that belongs to this ſubject; let it ſuffice to ſhew what uſe is made of triangles on this occaſion.

Fig. 56. And firſt of all chooſe a place from whence you may ſee many remarkable objects, as ſteeples, mills, caſtles, *&c.* and there meaſure a long line A B, from the extremities of which you may diſcover theſe remarkable objects; place the inſtrument or ſemi-circle at the point A, and fix a great ſtaff at the point B; put ſomething on the ſtaff, as a paper or handkerchief, in order to diſtinguiſh it from the point A; fix the ſemi-circle in ſuch a manner, as that looking through the vanes of its diameter, you may ſee the ſtaff fixed at the point B; this being done, take all the remarkable objects, C, D, E, F, that are before the line A B; which is done by imagining the lines A C, A D, A E, *&c.* and meaſuring the angles B A C, B A D, B A E, *&c.* ſet down upon paper the quantity of each of thoſe angles, with the name of the places C, D, E, *&c.* this is done by taking a line at will for the baſe, and drawing at one of its extremities as many indefinite lines as there are places obſerved, ſo as that the lines may make as many different angles with the baſe; on each of thoſe lines mark the name of the place to which they anſwer, and between each of them and the baſe make an arch, and in it mark the quantity of the angle which they make with the baſe.

When

When all the angles are thus meaſured and marked upon the paper, carry the ſemi-circle to the point B, then take away the ſtaff that was fixed there, and fix it at the point A, juſt where the inſtrument was placed; place the ſemi-circle at the point B, ſo as that looking through the vanes of its diameter, the ſtaff may be ſeen fixed at the point A; then imagine the lines B C, B D, B E, &c. and meaſure the angles A B C, A B D, A B E, &c. i. e. the angles which the places ſeen in the firſt working make with the other ſide of the baſe. Upon the ſame ſheet of paper draw, at the other extremity of the baſe, lines juſt in the ſame manner as was done for the angles ſeen at the point A, *i. e.* by writing along each of thoſe lines the name of the place ſeen, and drawing between them and the baſe arches in which is wrote the quantity of degrees which each of thoſe angles was obſerved to have. According to this ſecond working, all the poſitions C, D, E, &c. become tops of triangles which have the line A B for their common baſe; by this method the angles which each of thoſe triangles make with their baſe are known, and ſo is its baſe, conſequently three things are known which determine each of thoſe triangles, and ſo they are all determined.

Now to draw the figure upon paper, or which is the ſame thing, to make a clean draught of it, draw the line *a b*, and call it the length of the line A B meaſured upon the ground and at its extremities *a* and *b*; with the protractor make angles equal to thoſe that have been meaſured at the points A and B, the ſides of thoſe angles being lengthened, will cut one another in the points *c*, *d*, *e*, *f*, &c. which determine upon the map the ſituation of the places C, D, E, F, &c. obſerved upon the ground. Fig. 56, 57.

All the places which are on the other ſide of the baſe A B are taken and laid down in the ſame manner, and if you Fig. 56, 57.

you are willing to go farther on, take for a new baſe two poſitions F and E, already determined by the firſt workings; then take the poſition of thoſe places that are of either ſide of the new baſe, and take again another new baſe, and ſo on ſucceſſively until you have all the ſituations of the chief places of the country whoſe ſurvey is to be made. All the obſervations taken upon each baſe are laid down in the ſame manner as thoſe that were made on the firſt A B and the line *a b*, which is ſuppoſed to be of the ſame length as A B, is made a ſcale of, and for that reaſon is placed in ſome part of the map, and divided into the ſame number of fathoms that the line A B contains.

But, in obſerving the objects C, D, E, *&c.* care is to be taken, that thoſe places do not make, with the baſe A B, angles too acute or too obtuſe; wherefore the baſe A B muſt be as large as the ground will permit, for then the ſituations are taken more exact.

VI. *Of quadrilaterals.*

Fig. 58. A *quadrilateral* A is a figure terminated by four right lines.

Fig. 59. A *ſquare* C is a quadrilateral whoſe four ſides are equal, and angles right.

Fig. 60. A *parallelogram* D is an oblong quadrilateral, whoſe oppoſite ſides are parallel, and angles right.

Fig. 61. A *rhombus* or *lozange* E is a quadrilateral whoſe ſides are all equal, but angles oblique.

Fig. 62. A *rhomboïdes* F is an oblong quadrilateral whoſe oppoſite ſides are parallel, but angles not right.

Fig. 63. A *trapezium* G is a quadrilateral that has only two oppoſite ſides parallel.

A line C B drawn from the angle C to its oppoſite angle B in a quadrilateral, is called the *diagonal.* Fig. 64.

PROBLEMS.

1. *To make a ſquare upon a given line.* Fig. 65.

At the extreme points A and B of the given line, draw two perpendiculars A D, B C, each of them equal to the line A B, and join theſe perpendiculars with the line D C for the ſquare required.

2. *To make a parallelogram whoſe ſides are two given lines* A *and* B. Fig. 66.

Take a line E C equal to the given line A, and from the points E and C draw the perpendiculars E F, C D, each of them equal to the other given line B, and draw the line F D to have the rectangle required.

3. *To make a rhomboïdes whoſe ſides are two given lines* A *and* B, *with an angle equal to a given angle* C. Fig. 67.

Take a line D F equal to the given line A, and at its extremity D make an angle F D E equal to the angle C, and take D E equal to the other given line B; then from the point E, taken for center, and with the extent of the line A, deſcribe an arch on the ſide of F, and oppoſite to the point E, and from the point F, taken alſo for center, and with the extent of the line B, deſcribe another arch that cuts the firſt in a point G, and drawing from thence the lines G E, G F, you will have the rhomboïdes D F G E as required.

VII. *Of polygons.*

Figures that have more than four ſides are commonly called *polygons.* Amongſt which, that which has five ſides

is

is called a *pentagon*, that which has ſix an *hexagon*, that which has ſeven an *heptagon*, that which has eight an *octogon*, that which has nine an *enneagon*, that which has ten a *decagon*, that which has eleven an *undecagon*, and that which has twelve a *dodecagon*. As for the reſt of them, they are ſimply called polygons, only mentioning the number of their ſides; thus a polygon is ſaid to be of 15, of 20 ſides, *&c.*

A polygon is either *regular* or *irregular*.

Fig. 68, 69. A regular polygon A is that which has all its ſides and angles equal; and an irregular polygon B is that which has any inequality either in its ſides or angles.

Fig. 70. In a polygon B the angle A C D is called *ſaillant angle*, when its top C is without the polygon; and the angle E F G is called *re-entering angle*, when its top F is within the polygon.

Fig. 70. The center C of a regular polygon is a point C in the polygon, which is equidiſtant from all its angles.

There are two ſorts of radius's in a polygon, namely, a *direct* and an *oblique* one.

The direct radius C A is that which is drawn perpendicularly from the center C of the polygon, upon one of its ſides B D; and the oblique radius C D, that which is drawn from the center C of the polygon to one of its angles D.

Fig. 70. A polygon has two ſorts of angles, *the angle of the center*, and *the angle of the circumference*.

The angle of the center B C D is made by two oblique radius's C B, C D, drawn from the extremities B and D of the ſame ſide B D.

The angle of the circumference D E F is made by two ſides of the polygon D E, E F.

In all regular polygons, the direct radius cuts the ſides into two equal parts; and the oblique ones alſo divide

divide the angles of the circumference into two equal parts.

In order to prove that the direct radius CA biſſects the ſide BD, we obſerve, that the point C being equidiſtant from B and from D, and the line CA perpendicular to BD, all the points of CA muſt be likewiſe equidiſtant from B and from D; therefore BA is equal to AD. Therefore, &c. Fig. 70.

As for the oblique radius CD, we conſider that the point C is as equidiſtant from B and E, as the point D is alſo equidiſtant from the ſame two points; conſequently the line CD has all its points equidiſtant from B and E, therefore it will cut into two equal parts the arch deſcribed from the point D taken for a center between the ſides BD, DE; therefore it will cut the angle into two equal parts. Therefore, &c.

The angle of the center ACB of a regular polygon, added to the angle of the circumference BAD of the ſame polygon, are equal to two right ones. For the three angles of the triangle ACB are equal to two right ones, but the two angles of the baſe of the triangle CAB, CBA, which, together with the angle of the center ACB, are equal to two right ones, are equal to the angle of the circumference BAD. Therefore, &c. Fig. 71.

It follows from hence, that when the angle of the center of a regular polygon is known, the angle of its circumference is known alſo, ſince you need only take off from 180 degrees, *i. e.* from the ſum of two right angles, the angle of the center of the polygon.

As for the angle of the center of a regular polygon, it will always be found by dividing the ſum of four right angles, or 360 degrees, by the number of the ſides of the polygon. For all the angles of the center of a polygon are

equal to four right angles; but all thoſe angles are equal among themſelves. Therefore, &c.

Fig. 72. Hence it appears, that if from the center C of a regular polygon, and with the diſtance of one of its oblique radius's C A, a circle be deſcribed, the circumference of that circle will be divided by the ſides of the polygon, or by its oblique radius's, into as many equal parts as the polygon has ſides.

Fig. 73. A polygon thus contained in a circle, and whoſe angles are in the circumference of that circle, is ſaid to be *inſcribed in the circle*; and a polygon B, whoſe ſides touch the circumference of a circle, *i. e.* in which the circle is contained, is ſaid to be *circumſcribed about the circle.*

Fig. 74. The angles of any polygon are equal to twice as many right angles as the polygon has ſides leſs two; that is to ſay, that if from the ſum of the ſides of the polygon you ſubſtract two, its angles will be equal to twice as many right angles as there are ſides remaining; for a polygon can always be divided into as many triangles E B D, B D A, A D G, as there are ſides leſs two, by drawing the lines D A, D B, from an angle D, of the circumference to the other B and A; now the angles of each triangle are equal to two right ones. Therefore, &c.

The ſide of an hexagon is equal to the radius of the circle in which it is inſcribed.

Suppoſe A B the ſide of an hexagon. In order to prove that it is equal to the radius C A of the circle in which
Fig. 76. the hexagon is inſcribed, draw the radius C B, and you will have the triangle C B A, whoſe angle B C A will be the ſixth part of the whole circumference of the circle, or a third of the ſemi-circumference, ſince the ſides of the hexagon divide the circumference into ſix equal parts. Now the three angles of this triangle being equal to two right ones,

ones, they will be meaſured by the whole ſemi-circumference; the angle ACB will be meaſured by a third of it. The two angles CAB, CBA, taken together, will be therefore meaſured by the two other thirds; but thoſe two are equal, becauſe of the equality of the ſides CA, CB. Therefore they are each of them one third of the ſemi-circumference. Therefore the three angles of the triangle CBA are equal. Therefore its ſides are alſo equal. Therefore AB is equal to CA.

PROBLEMS.

1. *To inſcribe a ſquare in a given circle.* Fig. 75.

Draw two diameters AB, CD, that cut themſelves at right angles at the center E, they will cut the circumference of the circle into four equal parts, then draw the chord of each of thoſe parts.

2. The octogon will be had by dividing each arch that ſuſtains the ſide of the ſquare into two equal parts.

3. *To inſcribe an hexagon in a given circle.* Fig. 76.

Take the radius AC of the circle, and lay it in its circumference, it will divide it into ſix equal parts; then draw the chord of each of thoſe arches.

4. A dodecagon will be had by dividing each arch of the circle that contains a ſide of the hexagon into two equal parts, and then drawing the chord of each of thoſe arches.

5. *To inſcribe any regular polygon in a given circle.*

Divide the circumference of the circle into as many equal parts as the polygon has ſides, and draw the chord of each of thoſe parts.

The circumference of the circle cannot be divided geometrically into any given number of parts, that is to ſay,

only with a rule and compaſſes; but as for the inſcription of polygons in a circle, it muſt be done by trying, laying any opening of the compaſſes upon the circumference of the circle, and increaſing or diminiſhing it until it divides it into the ſame number of equal parts as the polygon is to have ſides. It may be done without trying, by means of a ſector. Upon that inſtrument there are two lines, on which are marked the ſides of polygons from the ſquare to the dodecagon.

In order, with this inſtrument, to inſcribe a polygon in a given circle, take with your compaſſes the length of the radius of the given circle, and the compaſſes remaining open, fix one of its feet at the point 6 of the line of the polygons, and open the ſector till the other foot of the compaſſes falls on the point 6, the other ſide of the ſector; the ſector remaining thus opened, if you want to inſcribe an heptagon in the given circle, take upon the line of the polygons the interval of 7 to 7; or from 9 to 9, if it is an enneagon; of 5 to 5, if it is a pentagon, *&c.* and lay that extent on the circumference of the circle, and it will divide it into 7, or 9, or 5, *&c.* equal parts.

If the radius of the given circle be too long to be laid on the line of the polygons, ſo as that the diſtance of 6 to 6 of the line of the polygons, in the greateſt opening of the ſector, be not ſo long as the radius of the given circle, deſcribe in that circle and from the ſame center a leſs circle, inſcribe in it the polygon required, and then draw the oblique radius of that polygon, which muſt be prolonged to touch the circumference of the given circle, and they will divide it into the ſame number of equal parts as the polygon is to have ſides.

Fig. 77. 6. *To make a figure equal and ſimilar to a given figure* ABCDE.

Divide

Divide the given figure into triangles by the lines DA, DB, drawn from one of the angles to the other; then draw a line *a b* equal to AB, on which make the triangle *a d b* equal to the triangle ADB, and on *b d* make the triangle *b d c* equal to the triangle BDC, and ſo on *a d* the triangle *a d e* equal to the triangle ADE; then the figure *a b c d e* will be had equal and ſimilar to that required.

This problem may be made uſe of to make a plan of any figure whatever; for if the figure ABCDE is ſuppoſed to be a ground or place whoſe draught or plan is to be taken, it muſt be divided into triangles by imagining the lines AD, DB, drawn in the figure. Meaſure thoſe lines, and all the out-lines of the figure; make a rough draught of it upon paper, and write on each of thoſe lines the number of fathoms they are found to be of on the ground. Now to make a clean draught of the figure, make a ſcale, and with it make triangles ſimilar to all thoſe that make up the figure ABCDE, and thoſe triangles will give the plan or figure of it in ſmall. For inſtance, ſuppoſe that the ſide AB has been meaſured, and found to be 106 fathoms; that the ſide AD has been meaſured, and found to be 140 fathoms; and the ſide BD of 102 fathoms. Fig. 77.

Now to make a draught of this triangle, make a ſcale, on which take 106 fathoms, which muſt be laid on a line *a b*, from *a* to *b*; then take 140 fathoms for the ſide AD; and from the point A, taken for center, and with the diſtance of 140 fathoms, deſcribe an indefinite arch; and as the ſide BD of the triangle ABD, is of 102 fathoms, take 102 fathoms on the ſcale; and from the point B, taken for center, and with that diſtance, deſcribe another arch that cuts the firſt in a point *d*, and drawing from thence the lines *d a*, *d b*, the triangle *a d b* will be had ſimilar to the triangle ADB. Fig. 77, 78.

The

Fig. 77, 78. The two triangles AED, BDC, will be had in the ſame manner, in order to have the whole plan *a b c d e* of the given figure.

If you cannot conveniently get within ſide the figure ABCDE, in order to take the plan of it, it muſt be taken from without, by meaſuring all the ſides AB, BC, &c. and all the angles ABC, BCD, &c. of that figure.

Fig. 77, 78. To draw it upon the paper, draw a line *a b*, and with the ſcale give it as many fathoms as the line AB has been found to have on the ground; and at its extremities *a* and *b*, make angles *a b c*, *b a e*, equal to the angles ABC, BAE, of *fig.* 77, and give the lines *b c*, *a e*, the ſame number of fathoms as the the lines BC and AE have; at the point C make the angle *b c d* equal to the angle BCD, and the ſide *c d* equal to the ſide CD; and ſo going on in the ſame manner, you will have the plan drawn *a b c d e* taken from without.

In order to know for certain if there be no miſtake in meaſuring the angles of a figure, you muſt add them all together, and ſee if their ſum total gives twice as many right angles as the figure has ſides leſs two; for inſtance, in the figure ABCDE, which has five ſides, the ſum of thoſe angles is equal to ſix right angles, or 540 degrees; if a greater or leſs quantity of degrees were found, there muſt have been ſome error in the meaſure of the angles, and the working muſt be begun again.

This method of taking and laying down a plan, gives us a draught which repreſents the length and breadth of the place propoſed. Thus *the plan of a town, or of a fortification*, repreſents the lengths and breadths of all its parts; and it may be conſidered as a ſection of the town or fortification, *parallel or level with the ſurface of the ground.*

In

In order to ſee the heights, another kind of draught is made uſe of called a *profile*, becauſe it repreſents a perpendicular ſection from the top to the bottom of the work.

By means of plans and profiles, lengths, breadths, and heights are ſhewn; but to repreſent its exterior appearance, another kind of draught or deſign is made uſe of, called an *elevation*.

Theſe three kinds of drawings are abſolutely neceſſary to give a complete view of a building; but the two former only are made uſe of in fortification.

We muſt not proceed further without treating of ſome of the properties of quadrilaterals; and that our obſervations may be more general, we ſhall conſider the parallelogram, the rhombe, and the rhomboïde, as quadrilaterals of the ſame ſpecies; and we ſhall call them all parallelograms, defining a parallelogram in the following manner, *viz.* *a quadrilateral, whoſe oppoſite ſides are parallel*; and that which has its angles right, we ſhall call *a rectangle parallelogram*, or ſhortly, a *rectangle*; and as to rhombes and rhomboïdes, whoſe angles are oblique and unequal, we ſhall call them *inclined parallelograms*.

Parallelograms are divided into two equal parts or triangles by their diagonals.

The triangles DAB, DBC, are equal, which are made by drawing the diagonal BD of the parallelogram ABCD, for DB is a common baſe to both triangles; and the lines AB, DC, being parallel, the angles ABD, BDC, are alternate angles, and conſequently equal; wherefore the two triangles DAB, DBC, having the ſame baſe, and the angles of the baſe of the former triangle being equal to the angles at the baſe of the other, theſe two triangles will be equal. Therefore, *&c.* Fig. 79.

From

From the equality of theſe two triangles DAB, DCB, it follows,

1. That the ſide AD is equal to the ſide BC, and the ſide AB to the ſide DC, ſo that *in every parallelogram the oppoſite ſides are equal.*

2. That the angle DAB is equal to the angle DCB, and the angle ADC is equal to the angle ABC, whence it follows that *in every parallelogram the oppoſite angles are equal.*

3. That the three angles of each of the triangles DAB, DCB, being equal to two right angles; *all the angles of the parallelogram taken together are equal to four right ones*; which is indeed true of all quadrilaterals, ſince the diagonal divides them into two triangles.

4. That if, thro' the extremities of two lines, AB, DC, being equal and parallel, two other lines AD and BC be drawn, theſe lines will be alſo equal and parallel, making a parellelogram with the two former.

VIII. *Of planimetry, or the meaſure of plane ſurfaces.*

1. *Planimetry* is that part of geometry which teaches how to meaſure the ſuperficies, area, or ſurface of figures; and as lines are meaſured by other leſſer lines, as with a fathom, a foot, &c. ſo likewiſe ſurfaces are meaſured by other leſſer ſurfaces, that is, with a ſquare fathom, a ſquare foot, &c.

2. A *ſquare fathom* is a ſquare of which every ſide is a fathom; and a *ſquare foot* is alſo a ſquare, every ſide of which is a foot.

Fig. 80. 3. *The ſurface of a rectangle* ABCD *is equal to the product of one of its ſides* AB, *by the other* BC.

For

For the rectangle ABCD may be conſidered as being filled with an infinite number of lines equal and parallel to AB, only ſeparated from one another by diſtances infinitely ſmall. Now it is evident, that there will be as many of theſe lines in the rectangle, as there are points or infinitely ſmall parts in its altitude BC; wherefore, in order to obtain the number of all theſe lines, *i. e.* the ſurface of the rectangle, you muſt multiply AB by BC. Therefore, *&c.*

If the ſide AB be 5 fathoms, and the ſide BC 4, by drawing lines parallel to the ſide BC, through the extremities of each of the fathoms of AB, the rectangle AC will be divided into 5 other rectangles, which will each of them have one ſide A 1; 1, 2, *&c.* containing one fathom, and another ſide equal to BC, containing four fathoms. Now if through the extremities of each of the fathoms of BC parallels to AB be drawn, theſe parallels will divide each of the five aforeſaid rectangles into four ſquares, each of them a fathom; wherefore the ſuperficies of this rectangle will be equal to five times four ſquare fathoms, *i. e.* to the product of AB multiplied by BC.

4. If inſtead of a rectangle parallelogram a ſquare was to be meaſured, it is evident that its ſuperficies would be had by multiplying one of its ſides by itſelf; for a ſquare may be conſidered as a rectangle with all its ſides equal: now in order to have the ſurface of a rectangle, you are to multiply one of its ſides by another. Therefore, *&c.*

5. So that when we multiply two lines together, or, which is the ſame thing, two numbers which expreſs the length of theſe lines, their product gives the ſurface of a rectangle, whoſe ſides will be theſe lines or numbers. And likewiſe when we multiply a number by itſelf, its product gives the ſurface of a ſquare, whoſe ſide is the given number. Thus a fathom being ſix foot, a ſquare fathom will

be 36 ſquare feet; and a ſquare foot will be 144 ſquare inches.

6. Whence we are to take notice, that if we are to reduce ſquare fathoms into ſquare feet, we muſt multiply them, not by 6, the number of feet in a fathom; but by 36, the number of ſquare feet which are in a ſquare fathom; and that, in order to reduce ſquare feet into ſquare inches, we muſt multiply them by 144, *i. e.* by the number of ſquare inches that are contained in a ſquare foot; and on the other hand, to reduce ſquare feet into ſquare fathoms, we muſt divide them by 36; and laſtly, to reduce ſquare inches into ſquare feet, we muſt divide them by 144.

7. When any figure is to be meaſured, we muſt find, according to what has been laid down, how many ſquares of ſome known meaſure or other the ſurface of the figure contains; but it is manifeſt that the rectangle and the ſquare are the only polygons that can be divided into equal ſquares by the means of lines drawn parallel to their ſides, and that therefore it is the ſurfaces of theſe figures only that can be had in ſquare meaſures by multiplying of one ſide by the other; wherefore in order to get the ſurface of inclined parallelograms, as alſo that of other polygons, rectangles equal in ſurface to theſe figures are to be found, whoſe ſurfaces being known, give thoſe of the figures that are equal to them. We muſt obſerve,

I.

8. That as all figures are meaſured by the ſquare, the lines that are multiplied together in order to obtain the ſuperficies of the figure ought to be perpendicular to one another, otherwiſe their product can never become ſquares.

9. That

2.

9. That in parallelograms, as well as in triangles, you may take which ſide you pleaſe for a baſe, and then the height of the parallelogram will be a perpendicular line drawn down to the baſe from the oppoſite ſide.

3.

10. That the height of a triangle is a perpendicular let down from the top upon the baſe lengthened out, wherever this perpendicular falls without the triangle.

4.

11. That it is the ſame thing to ſay, that two figures are equal in height, as to ſay that they are between the ſame parallels, becauſe all perpendiculars between the ſame parallels are equal, and theſe perpendiculars are taken for the heights of figures.

5.

12. That when two figures are ſaid to be equal, it follows not from thence that they are ſimilar or like, but only that they have equal ſurfaces. Thus a triangle is equal to a ſquare, if its ſurface be equal to that of the ſquare; wherefore, when figures which contain equal ſurfaces are terminated by lines that make equal angles, they are ſaid to be *ſimilar* and *equal.*

13. *Parallelograms upon the ſame baſe, and between the ſame parallels, are equal.*

Let the parallelograms ABCD, ABEF, be on a common baſe AB, and between the ſame parallels DE, AH, we ſay, they are equal. Fig. 81.

For their oppoſite ſides are equal, *i.e.* AD to BC, and AF to BE; and alſo the ſide AB to DC and FE; now if to each of theſe ſides DC and FE you add the line CF, you will have DF equal to CE; conſequently the three ſides of the triangle ADF equal to the three ſides of the

triangle BCE; wherefore theſe two triangles will be equal; but theſe triangles have the triangle CGF common to both; wherefore taking it away, you will only leſſen the two triangles ADF, BCE, by an equal quantity, and what remains, the two trapeziums AGCD, BEFG, will be equal; now if to theſe two trapeziums you add the triangle ABG, it is evident that the figures ABCD and ABEF will be equal, which figures are the given parallelograms. Therefore, *&c.*

It follows from this propoſition,

1.

14. *That parallelograms that have equal baſes, and that are between the ſame parallels, are equal.*

Fig. 82. For let the parallelograms ABCD, EFGH, be upon the equal baſes ABEF, and between the ſame parallels AF, DH; if you draw the line AH, BG, you will have a third parallelogram ABGH equal to the parallelogram ABCD, by the foregoing propoſition; and alſo to the parallelogram EFGH; now two things equal to a third, are equal between themſelves; wherefore the two parallelograms ABCD, EFGH, are equal. Therefore, *&c.*

2.

15. *That every inclined parallelogram is equal to a rectangle of the ſame baſe and height with it*; ſo that its ſurface will be had in the ſame manner, *i. e.* by multiplying its baſe by its height.

16. *Triangles that have equal baſes and equal heights, or that are between the ſame parallels are equal.*

Fig. 83. Let the triangles ABC, DEF, have equal baſes AB, DE, and be between the ſame parallels AE, CH, we ſay, they are equal.

For draw the lines BG, EH, parallel to the ſides AC, DF, and they will make the parallelograms ABGC, DEHF, which

which are equal by the foregoing propoſition; but the triangles ABC, DEF, are the halves of theſe parallelograms, becauſe the diagonal CB, EF, divide the parallelograms into two equal parts; wherefore they are equal. Therefore, *&c.*

17. So that in order to get the ſurface of a right angle triangle, you muſt multiply the two ſides which make the right angle together, then take half the product for the ſurface; but if the triangle be not right angled, multiply the baſe by the height, and take the half of that product. Or elſe multiply the baſe by half the height, or the height by half the baſe.

18. Whence it follows, that a triangle is equal to a parallelogram when its baſe is equal to that of the parallelogram, and its height double the height of the parallelogram, or elſe the height being the ſame, its baſe be double that of the parallelogram; and laſtly, that triangles are halves of parallelograms of the ſame baſes and heights.

19. *A Trapezium is equal to a triangle whoſe baſe is a line equal to the two parallel ſides of the trapezium, and its height the perpendicular drawn between thoſe ſides.*

Prolong the baſe AB of the trapezium ABCD indefinitely towards E, then draw the diagonal DB, and from C draw CE parallel to DB, which will cut AB prolonged to E, then draw the line DE; now becauſe CE is parallel to DB, and DC to BE, BECD will be a parallelogram; therefore BE is equal to DC, and the triangle AED will have for its baſe a line AE equal to the two parallel ſides of the trapezium, and its height will be the perpendicular DF drawn between the parallel ſides of the trapezium; then this triangle is equal to the trapezium ABCD. Fig. 84.

For

For the triangle ADB is common both to the trapezium ABCD and the triangle ADE, and the triangle DBC, which completes the trapezium, is equal to the triangle DBE, which completes the triangle ADE, becauſe they are upon the ſame baſe DB, and between the ſame parallels DB, CE; therefore the triangle AED is equal to the trapezium ABCD. Therefore, *&c.*

20. It follows from this propoſition, that in order to have the ſuperficies of a trapezium, you muſt multiply the ſum of both its parallel ſides by the half of its altitude, or elſe, the half of the ſum of its two parallel ſides by its altitude; ſo that a trapezium is equal to a parallelogram that has for its baſe the half of the ſum of its two parallel ſides, and for its altitude the perpendicular drawn between thoſe ſides.

21. Every quadrilateral being divided into two triangles by its diagonal, in order to get the ſuperficies of any irre-
Fig. 85. gular quadrilateral, ſuch as ABCD, draw the diagonal DB, and find the ſuperficies of each of theſe triangles ABD, DBC, made by the diagonal and the ſides of the quadrilateral; this is done by taking the diagonal BD for the baſe of each of theſe triangles, and drawing the perpendiculars AE, CF, from the points A and C to BD, being the heights of the triangle ABD, DBC; by which means the ſurfaces of each of theſe triangles will be had according to the foregoing rules, and the ſum of them will give you the ſurface of the quadrilateral ABCD.

22. *A regular polygon is equal to a triangle whoſe baſe is a line equal to the ſum of all the ſides of the polygon, and whoſe height is its direct radius, or, which is the ſame thing, a perpendicular drawn from the center of the polygon to one of its ſides.*

For

For all regular polygons, as ABDEF, may be divided into as many triangles as they have ſides, by drawing oblique radius's, CA, CB, &c. from their center C; all theſe triangles, CAB, CBD, &c. are equal, the given polygon being regular. Wherefore its ſurface will be equal to that of as many triangles (each of them equal to the triangle ABC) as the polygon has ſides. Now if you lengthen the ſide AB towards L, and take BH, HI, IK, &c. equal each of them to the baſe AB of the triangle ABC, ſo that the ſide AL be equal to the ſum of all the ſides of the polygon ABDEF, and if you draw the lines CH, CI, &c. you will have all the triangles ABC, BHC, HIC, &c. equal, as having each of them equal baſes and a common altitude CG. Therefore the triangle ACL will conſiſt of as many equal triangles as the given polygon, and the ſum of theſe triangles will be equal to the ſum of thoſe of the given polygon; therefore the triangle ACL will be equal to the polygon ABDEF. Now to get the ſurface of this triangle, multiply the baſe AL by half the altitude CG. This baſe is the ſum of all the ſides of the polygon, and CG is its direct radius. Therefore to get the ſurface of a regular polygon, multiply the half of the ſum of the ſides by the direct radius, or elſe the ſum of the ſides by the half of that radius. Fig. 86.

23. It follows from this propoſition, *that a circle is equal to a triangle* ABC, *whoſe baſe is a line* AB, *equal to the circumference of the circle, and its altitude its radius* CA. Fig. 87.

For the circle may be conſidered as a regular polygon conſiſting of an infinite number of ſides; which ſides muſt conſequently be infinitely ſmall; now according to this ſuppoſition, the radius of the circle becomes the direct radius of the polygon. But by the foregoing propoſition,

a regular polygon is equal to a triangle that has for its baſe the circumference of the polygon, and for its altitude its direct radius. Therefore, *&c.*

24. So that for the ſuperficies of the circle you multiply its circumference by half its radius, or the fourth part of its diameter.

The meaſuring of a circle, and of other curvilinear or mixtilinear figures, is called *their quadrature*; becauſe theſe figures cannot be meaſured but by reducing them to rectilinear figures, whoſe common meaſure is the ſquare. So that, to find the *quadrature of the circle* ſignifies no more than to find the ſuperficies of a rectilinear figure equal to the circle. But it has been juſt now proved, that a circle is equal to a triangle whoſe baſe is the circumference of the circle, and its altitude the radius; wherefore if the circumference of the circle were truly known, we ſhould be able to ſquare it; but hitherto this line has not been found out with a geometrical preciſion, though it has been a ſubject in which mathematicians have greatly exerciſed themſelves; and all the benefit ariſing from their labour is no more than the having methods whereby we may come nearly to the true proportion this line bears to the diameter of the circle; and theſe approximations are ſuch, that if the circumference of the circle were intirely known, it would hardly produce a greater exactneſs in practice. Nay, the exacteſt proportions are ſeldom made uſe of; that found by *Archimedes*, the famous geometrician of *Syracuſa*, who flouriſhed about 1950 years ago, being the only one which generally ſerves for common uſe.

25. According to this approximation, the diameter of a circle being divided into ſeven equal parts, the circumference will contain 22 equal parts, *i. e.* the diameter will be a little leſs than the third part of the circumference; ſo that

that the diameter of a circle is to its circumference nearly as 7 to 22.

As all circles are ſimilar figures, this propoſition is the ſame in all circles; ſo that if the diameter of any circle be divided into ſeven equal parts, its circumference will ever contain 22 of thoſe parts, with a very minute difference only.

26. It follows from hence, that the diameter of a circle being known, its circumference is found by the *rule of three.* The two firſt terms will be always 7 and 22; the third, the given diameter; and the fourth, which comes out, will be the circumference required. For inſtance, ſuppoſe it were required to find the circumference of a circle whoſe diameter is 15 fathoms, place your terms in the following manner; 7: 22 :: 15; that is, 7 is to 22, as 15 is to a fourth term, which will come out 47 $\frac{1}{7}$ fathoms, which is the circumference of a circle whoſe diameter is 15 fathoms.

27. If on the contrary, the circumference of the circle be given, ſuppoſe 60 fathoms, only reverſe the terms of the rule, and ſay, 22: 7:: 60: to a fourth term, which will be 19 ($\frac{2}{11}$ *i. e.*) $\frac{1}{11}$ fathoms, for the diameter of a circle whoſe circumference is 60 fathoms. Thus, to find the diameter of the earth, or the diſtance there is between that part of the world we live in, and that which is diametrically oppoſite to it, which is called *the antipodes*, ſuppoſing the earth quite ſpherical, and that its circumference be 9000 leagues, ſay, 22: 7:: 9000 leagues: to a fourth term, which will be 2863 leagues for the diameter of the earth.

28. A *ſector* is the portion of a circle CAD contained between two radius's CA, CD, and an arch AD. A *ſegment* is a part of a circle ABD contained between a chord AD and an arch ABD. Fig. 88, 89.

29. The ſuperficies of a ſector is had by multiplying its arch by half the radius. For as the whole circle is equal to a triangle whoſe baſe is the circumference, and height the radius, in the ſame manner a part of the circle contained within two radius's and an arch is equal to a triangle whoſe baſe is that arch, and height the radius; now to find the ſuperficies of this triangle, you muſt multiply its baſe by half its height. Therefore, *&c.*

Fig. 88. 30. Now in order to find the arch of a ſector, the radius AC and the angle ACB being given, find out the contents of the whole circumference firſt, whoſe radius is AC; and then by the *rule of three*, ſay, if 360 degrees, the whole circumference, give ſo many fathoms, how many fathoms will the degrees of the arch of the ſector give? the fourth term will give you the fathoms of the arch of the ſector ACB.

Fig. 89. 31. The ſurface of a ſegment ABD is had by firſt finding that of the ſector CABD, and ſubſtracting from this ſurface that of the triangle CAD; it is evident, that the remainder will be the ſurface of the ſegment ABD.

32. In order to meaſure any irregular figure, divide it into parallelograms, triangles, trapeziums, *&c.* find the ſurfaces of theſe figures ſeparately, and then add them all together; their ſum will exhibit the ſuperficies of the given figure.

The following propoſition is the famous 47th of the firſt book of *Euclid*'s *Elements*. They ſay it was found out by *Pythagoras*, who ſacrificed an hecatomb, *i. e.* a hundred oxen to the muſes, by way of an acknowledgment for ſo great a diſcovery. And indeed it is of the greateſt uſe, as well in that part of geometry which is called *common* or *elementary*, as in *higher* or *ſublime geometry*, in which the properties of curved lines are demonſtrated; but in this ſhort treatiſe

treatiſe we cannot go through all the uſes of it; however, the propoſition itſelf ought to be known by every one that has the leaſt tincture of geometry; we ſhall therefore inſert it with its demonſtration; but if it ſhould be thought unneceſſary by ſome, it may be paſſed over without any inconveniency for the ſequel of this treatiſe.

33. *In every right-angled triangle, the ſquare of the hypothenuſe (the line that ſubtends the right angle) is equal to the ſquares of the two other ſides taken together.*

For, let the triangle ACB be right-angled; the ſquare AF made on the hypothenuſe AB, is equal to the ſquare CG made on the ſide CB, and to the ſquare AM made on the ſide AC. Fig. 90.

From the top of the right angle C draw a perpendicular CD to the ſide EF, which will cut AB in L, then draw the lines CE, CF, AG, and BH; this being done, the perpendicular LD divides the ſquare AF into two rectangles AD, BD. The triangle AEC is half the rectangle AD, and the triangle FBC is half the rectangle BD. For they are upon the ſame baſe AE, BF, and are between the ſame parallels, CD being parallel to each of thoſe baſes. For the ſame reaſon the triangle HAB is half of the ſquare HC, and the triangle GBA half of the ſquare BN. If therefore it be demonſtrated, that the triangle AEC is equal to the triangle HAB, it will follow that the rectangle AD will be equal to the ſquare AM; as alſo if the triangles BFC, GBA, are equal, the rectangle BD will be equal to the ſquare BN; now theſe two rectangles DA, DB, together, are the ſquare of the hypothenuſe AB; wherefore we ſhall have the ſquare of this ſide equal to the ſquares of the two other ſides. Now nothing remains but to prove the equality of thoſe triangles, which is done as follows.

The two triangles AEC, AHB, have their ſides AE and AB equal, being ſides of the ſame ſquare AF; their ſides AC and AH are alſo equal, being ſides of the ſquare AM; and their angles CAE, BAH, contained between theſe ſides are equal, becauſe they are each of them made up of a right angle, and of the angle CAB common to both; therefore theſe two triangles are entirely equal. In the ſame manner the two other triangles FBC, BGA, will be demonſtrated to be equal. Therefore, *&c.*

It follows from this propoſition,

L.

34. That if the two ſides CA, CB, of a right-angle triangle, which make the right angle, be given, the hypothenuſe AB is found; for by ſquaring both thoſe ſides, and adding them together, the ſquare root of the ſum of thoſe two ſquares will give the hypothenuſe.

Thus ſuppoſing the ſide AC to be three fathoms, and the ſide CB four, add the ſquare of 3 which is 9, to the ſquare of 4 which is 16, and extract the ſquare root of their ſum, 25, which will be 5 fathoms for the length of the hypothenuſe AB.

35. If inſtead of the two ſides which make the angle, the hypothenuſe and one of thoſe ſides were given, it is evident, that the other ſide is had by ſubſtracting the ſquare of the given ſide from the ſquare of the hypothenuſe, and extracting the ſquare root of the remainder.

2.

36. That a ſquare may be made equal to two other ſquares, by taking a ſide of each of theſe ſquares, and making them the ſides of a right-angle triangle; for the ſquare of the hypothenuſe of this triangle will be equal to the two other given ſquares.

That

That a ſquare may be made double, triple, quadruple, &c. of another ſquare. For if a right-angle triangle be made in ſuch manner that each of the ſides which contain the right angle be equal to the ſide of the given ſquare, the ſquare of the hypothenuſe of this triangle will be double the given ſquare. And if you take the hypothenuſe of this triangle, and one of the ſides of the given ſquare for two ſides, containing a right angle in another right-angle triangle, it is evident, that the ſquare of the hypothenuſe of this triangle will be triple the given ſquare. In purſuing this method, you will have a ſquare quadruple, quintuple, &c. of another ſquare.

37. This propoſition may alſo be made uſe of to erect a perpendicular on a given line at the extremity of that line. For inſtance, ſuppoſe a perpendicular was to be raiſed at the extremity A of the line AB; take a part A 1 at pleaſure, and lay it four times upon AB from the point A to the point 4; and from this point, as a center, with the diſtance 5 of theſe parts, deſcribe the arch of a circle over A; then taking the point A for center, with the diſtance of three parts on AB, deſcribe another arch cutting the former in the point C, a line drawn from the point C to the point A will be the perpendicular required. For draw the line C 4, the ſquare of this line, 25, will be equal to the ſquares 9 and 16 of the ſides AC, A 4; therefore the triangle CA4 will be a right-angle triangle, and the line C 4 the hypothenuſe of this triangle; therefore the line CA will be perpendicular to the line AB. Fig. 91.

IX. *Of ſolids.*

1. Extenſion, conſidered with length, breadth, and depth, is called a *body* or *ſolid*.

2. The

2. The extremities of bodies are ſurfaces, as the extremities of ſurfaces are lines, and thoſe of lines are points.

3. A line is perpendicular to a plane, when it makes right angles with all the lines of the plane on which it falls.

4. Two planes are parallel, when all their perpendiculars drawn between them are equal.

5. When two planes cut one another, or meet, they do it in a right line common to both planes; wherefore this line is called *the common ſection of theſe planes.*

6. A plane is either perpendicular or oblique to another plane, according to the angle which perpendiculars make drawn on thoſe planes to their common ſection, through one and the ſame point; thus two planes meeting one another, make only a plane angle; but if more than two planes meet in a point, *as at the corner of a dice*, they make an angle called *a ſolid angle.*

7. A *pyramid* is a body bounded by triangles, whoſe tops meet in a point, and whoſe baſes make a plane rectilinear figure, which is called the baſe of the pyramid; as
Fig. 92. the body ABCDE, bounded by the triangles ABE, ABC, *&c.* whoſe tops meet in the point A, and whoſe baſes make the quadrilateral BCDE.

8. The ſolid angle A of the pyramid is called its *vertex*, and the line AF falling perpendicularly from the vertex of the pyramid to the plane of the baſe, is the altitude of the pyramid. If the baſe of the pyramid be a triangle, it is called a *triangular pyramid*; if the baſe be a quadrilateral, it is called a *quadrilateral pyramid*; and ſo on, according to the figure of the baſe.

9. If the baſe of the pyramid be a circle, it may be conſidered as bounded by an infinite number of ſmall triangles, which all together form a curve ſurface BAC; ſuch a
Fig. 93. round pyramid is called a *cone.*

10. The

10. The point A is the vertex of the cone, as in the pyramid, and the line AD drawn, from the vertex A to D the center of the cone's baſe, is called its *axis*. When this line is perpendicular to the baſe, the cone is ſaid to be a *right* one; if otherwiſe, oblique; and its height like the pyramid's is meaſured by a perpendicular let down from the vertex to the baſe.

11. The line AB drawn from A the vertex of the cone to a point B in the circumference of the baſe is called *the ſide of the cone.*

12. If the upper part of the pyramid or cone be cut off, the pyramid or cone is ſaid to be *truncated.*

13. A *priſm* is a ſolid, the plane of whoſe baſe and that of its top are parallel, equal, and ſimilar, and which is bounded on the other ſides by parallelograms. As is the ſolid AG, whoſe baſe is the quadrilateral ABCD, equal and ſimilar to the quadrilateral EFGH, and which is bounded on all the other ſides by the parallelograms ADFE, ABHE, *&c.* Otherwiſe a priſm is a ſolid that has two oppoſite ſides parallel, equal, and ſimilar, and its other ſides parallelograms. Fig. 94.

14. If the baſe of a priſm be a triangle, it is called a *triangular priſm*; if it be a quadrilateral, a *quadrilateral priſm*; and ſo on, according to the polygon of the baſe.

15. If the baſe of the priſm ſhould be a parallelogram, it will then be bounded on all ſides by parallelograms, and it is then called a *parallelipiped.*

16. If the baſe of the priſm be a circle, this and the ſuperior circle will be joined together by an infinite number of ſmall parallelograms which form a curve ſuperficies, and ſuch a ſolid is called a *cylinder.* You may imagine a cylinder by a column equally great from top to bottom, or elſe by a number of draughtmen laid equally one upon the other. Fig. 95.

17. The

17. The line AB, drawn from A the center of the ſuperior circle of the cylinder, thro' B the center of its baſe, is called the *axis* of the cylinder.

18. Priſms, parallelipipeds, and cylinders, are either *right* or *oblique*; they are right when the planes which join their baſes make right angles with them; if otherwiſe, they are oblique; and then their height is meaſured by a perpendicular drawn from the plane parallel to the baſe upon that of the baſe, lengthened out, if it be neceſſary.

Fig. 96. 19. A *ſphere*, or a *globe*, is a ſolid bounded by one curve ſurface, whoſe points are all of them equally diſtant from one point C in the ſolid, which is called its *center*.

Fig. 97. 20. You may imagine a ſphere or a globe to be generated by the motion of a ſemi-circle ADB round its diameter AB; and then it will be evident,

1.

That C the center of the ſemi-circle ABD is the center of the ſphere alſo.

2.

That all lines as CD, CF, drawn from C, the center of the ſphere, to its ſuperficies, are equal. Theſe lines are called *radius's* or *ſemi-diameters of the ſphere.*

3.

That all lines as AB, EF, drawn through C, the center of the ſphere, and which terminate at either end in its ſuperficies, are equal, being only two equal radius's. Theſe lines are called *the diameters of the ſphere.* Among theſe diameters, the diameter AB, on which you ſuppoſed the ſemi-circle ADB to be moved for the generation of the ſphere, is called *its axis*; ſo that the axis of a ſphere or globe is always one of its diameters. The extremities A and B of the axis of the ſphere, are called its poles.

4. That

4.

That all lines as GH, by the motion of the ſemi-circle ADB, deſcribe circles parallel to one another, and perpendicular to the axis AB; and they are called *parallel circles*. The greateſt of thoſe circles is that which is made by the radius DC, which is equally diſtant from the poles A and B.

5.

That all parallel circles deſcribed by the lines GH, KL, which are equally diſtant from the poles A and B, are equal.

6.

That every circle ADBFA, which paſſes through C the center of the ſphere, divides it into two equal parts. For, if inſtead of imagining the ſphere to be made by the motion of the ſemi-circle ADB, you ſuppoſe it to be made by the motion of the whole circle ADBFA about its diameter AB, it is eaſily perceived, that as the ſemi-circle ADB gets into the place of BFA, the ſemi-circle BFA will in the ſame manner get into the place of ADB; ſo that whilſt the ſemi-circle ADB deſcribes one half of the ſphere, the ſemi-circle BFA will deſcribe the other half; therefore the ſphere will be divided into two equal parts by the circle, ADBFA. Therefore, *&c.*

21. All circles which paſs through the center of the ſphere, and which conſequently divide it into two equal parts, are called *great circles of the ſphere*, and are all equal.

Other circles which cut the ſphere without paſſing thro' its center, are called *leſſer circles*; ſo that it is manifeſt from what has been ſaid, that leſſer circles divide the ſphere into two unequal parts.

22. A *zone* is that part of a ſphere which is contained between two of its parallel circles, ſo called from its being a kind of belt or girdle going round the ſphere.

23. Beſides the bodies which we have defined, there are five others which are called *regular*, becauſe they are bounded by regular, ſimilar, and equal figures. Theſe ſolids are otherwiſe known by the general name of the five *Platonic* bodies.

1.

* The *tetrahedron*, or *regular pyramid*, terminated by four equilateral triangles.

2.

The *hexahedron*, or *cube*, bounded by ſix ſquares. This is repreſented by a common dice.

3.

The *octahedron*, terminated by eight equilateral triangles.

4.

The *dodecahedron*, terminated by twelve pentagons.

5.

The *icoſahedron*, terminated by twenty equilateral triangles.

24. There are no more than theſe five regular bodies, and it will be plain from the following demonſtration that there can be no more.

Three plane angles at leaſt are required for the making of a ſolid angle, and let the number of plane angles which make this ſolid angle be what it will, their ſum muſt be leſs than four right angles, or 360 degrees; for it is plain that if theſe angles become equal to four right angles, the ſolid angle vaniſhes or diſappears. Now in order to make a regular body, it muſt be done by regular figures, and there muſt be three angles of thoſe figures at leaſt taken for the making of a ſolid angle, and theſe muſt be leſs than four right angles. Now the angles of an equilateral triangle

* The figures of theſe five ſolids are omitted, for they are not eaſily to be apprehended by being drawn on paper; it is requiſite to have them made in wood or paſteboard, or the like.

triangle are each of them equal to 60 degrees, you may therefore make a ſolid angle by putting three of thoſe angles together, and it will be that of the regular pyramid. You may alſo make a ſolid angle with four of them, and it will be that of the octahedron; or with five of them, and it will be that of the icoſahedron; but ſix of them are equal to 360, or four right angles; therefore you cannot make a ſolid angle with ſix angles belonging to equilateral triangles; therefore theſe triangles cannot ſerve in this caſe but for the making of the regular pyramid, the octahedron, and the icoſahedron.

Four angles of a ſquare cannot make a ſolid angle, and therefore you can make one but with three only, which is that of the cube.

The angle of the circumference of a regular pentagon is 108 degrees, three of theſe angles make 324; ſo that they are leſs than four right angles, or 360, and conſequently may make a ſolid angle, *viz.* that of the dodecahedron; but four of theſe angles exceed 360 degrees; therefore you cannot make any other ſolid angle with the angles of pentagons, but that of the dodecahedron.

The angle of the circumference of an hexagon is 120 degrees, three of which make 360 or four right angles; conſequently you can make no ſolid angle with them. The angle of the circumference of regular polygons above the hexagon, is greater than that of the hexagon; therefore you cannot make a ſolid angle with the angles of any of thoſe polygons. Therefore, *&c.*

PROBLEMS.

25. *To let fall a perpendicular upon a plane, from a point without the plane.*

Let the point A be out of the plane FG upon which the perpendicular is to be drawn. Put one foot of your com- Fig. 98.

paſſes upon A, and with the other mark three points B, D, E, in the plane FG; then find the center C, of a circle, whoſe circumference will go through theſe three points; draw the line AC, and it will be the perpendicular required.

For, by the conſtruction, the point A and the point C are each of them equidiſtant from the points B, D, E; therefore the line AC does not incline more on one ſide than on the other towards the plane FG; wherefore it will make right angles with all the lines drawn on this plane, which go through the point C. Therefore, *&c.*

26. *From a point given in a plane, to raiſe a perpendicular to the plane.*

In order to do this, you muſt make uſe of a *ſquare*, which is an inſtrument compoſed of two rules made of copper, iron, or wood, which are joined together in a right angle. Lay one of theſe rules on the plane, ſo as that the top of the right angle of the ſquare be upon the given point, and a line drawn from that point along the other rule will be the perpendicular required.

X. *Of the meaſure of the ſurfaces of bodies.*

1. As bodies of which we have juſt now treated, are bounded by ſurfaces whoſe dimenſions are found in the article of planimetry, it follows, that the ſurface of theſe bodies is eaſily had by taking that of all the figures by which they are bounded. We muſt only obſerve,

2. That as a cylinder may be conceived to be bounded by an infinite number of ſmall, equal parallelograms, having all their baſes and altitudes equal, all theſe parallelograms will be equal to a parallelogram whoſe baſe is equal to all their baſes, *i. e.* the circumference of the baſe of the cylinder,

der, and whoſe height is the height of theſe parallelograms, which is that of the cylinder; now the ſurface of a parallelogram is meaſured by multiplying the baſe into the height; therefore the ſurface of a cylinder, excluſive of its baſes, is meaſured by multiplying the circumference of its baſe into its height.

3. You may in like manner conceive the ſurface of a right cone to be made up of an infinite number of ſmall equal triangles, whoſe tops are united in that of the cone; now imagine all theſe triangles to be taken off the cone and laid flat on a plane, they will make a ſector whoſe radius is the ſide of the cone, and whoſe arch is the circumference of the baſe of the cone; now the meaſure of the ſector's ſurface is had, by multiplying its arch by half its radius; therefore the meaſure of a cone's ſurface is had by multiplying the circumference of the cone's baſe by half its ſide.

4. If a right cone be truncated, ſo that its upper part be cut off by a plane perpendicular to the axe of the cone, then all the little triangles that were conceived to form the ſurface of the cone will be changed into as many trapeziums, which, taken all together, will be equal to one trapezium, whoſe height is what remains of the ſide of the cone, and whoſe parallel ſides are the circumference of the baſe of the cone and that of the truncated part. Now a trapezium is meaſured by multiplying the ſum of its two parallel ſides by half of its height; therefore the ſurface of a right truncated cone is meaſured by multiplying the ſum of the circumference of its baſe, and of that of the truncated part by half of the ſide which is between its baſe and that part.

As the following propoſition, and ſeveral others in the following article, cannot be demonſtrated without other propoſitions that we thought proper to omit for brevity ſake,

we

we ſhall not therefore here attempt it; but they may be taken for granted, and recourſe may be had to books where they are demonſtrated, if they are not to be admitted but under the force of evidence.

5. *The ſurface of a ſphere is equal to that of a cylinder, excluſive of its baſes, whoſe baſe is a great circle of the ſphere, and height its diameter.*

The ſurface of a cylinder, excluſive of its baſes, is meaſured by multiplying the circumference of its baſe by its height; therefore the ſurface of a ſphere is meaſured by multiplying the circumference of a circle whoſe diameter is that of the ſphere by this ſame diameter, *i.e.* a great circle of the ſphere by its diameter.

6. Thus, to meaſure the ſurface of the earth, multiply the circumference of its great circle, which was found to be 9000 leagues, by its diameter, which was alſo found to be 2863 leagues, and the product of theſe two numbers (25,767,000 ſquare leagues) will be the ſurface of the whole terreſtrial globe.

XI. *Of ſtereometry, or the meaſuring of ſolids.*

1. Solids are meaſured by leſſer ſolids, as ſurfaces are by other leſſer ſurfaces. Now as the ſquare is the meaſure of ſurfaces, ſo is the cube that of ſolids; ſo that as we made uſe of ſquare fathoms for the meaſure of ſurfaces, we ſhall make uſe of *cubic fathoms* for meaſuring of bodies.

2. A *cubic fathom* is a cube bounded by ſix ſquare fathoms, and a *cubic foot* is a cube bounded by ſix ſquare feet; and a *cubic inch* is a cube bounded by ſix ſquare inches, &c.

3. *The ſolidity of a right parallelipiped is equal to the product of the baſe multiplied by the height.*

Fig. 99. Suppoſe the parallelipiped A F; in order to prove that its ſolidity is equal to the product of the baſe D C F E, multiplied by

by the height DA, you muſt imagine the ſolid to be made up of as many figures equal and ſimilar to the baſe DCFE as there are points in its height DA; now to get the ſum of all theſe figures, that is the ſolidity of the parallelipiped AF, it is plain you muſt multiply DF by DA. Therefore, *&c.*

If the ſide DE of the rectangle DF be five fathoms, and the ſide DC 4, the ſurface of this rectangle will be 20 ſquare fathoms. If you divide the rectangle into 20 ſquare fathoms by parallels to the ſides DE, DC, and imagine planes to be drawn through all thoſe parallels perpendicular to the rectangle DF, thoſe planes will divide the whole ſolid AF into 20 parallelipipeds, each of which will have for its baſe a ſquare fathom, and its height the line DA, which is here ſuppoſed to be ſeven fathoms. Then ſuppoſe that at the extremity of each of the fathoms of the ſide DA, planes be drawn parallel to the rectangle DF, thoſe planes will divide each of thoſe 20 parallelipipeds of which AF is made up into ſeven cubes, each of them a cubic fathom; ſo that, in the whole parallelipiped AF, there will be 20 times as many cubic fathoms as there are fathoms in its height DA; hence it appears, that in order to have the number of cubic fathoms of which AF is made up, you muſt multiply the ſurface of its baſe DF by its height DA. But that number of cubic fathoms is the ſolid of the parallelipiped. Therefore, *&c.*

4. If the baſe DF of the parallelipiped AF is a ſquare, and its height DA be equal to the ſide DC of that ſquare, it is evident that the parellelipiped AF will be a cube, and its ſolidity will be had in the ſame manner by multiplying its baſe DF by its height DA.

5. It follows from hence, that a ſurface multiplied by a line gives a ſolid. Now every ſurface may be conſidered as the product of two lines; therefore the product of three lines, or of three numbers, each of which expreſs the quan-

tity

tity of one of thoſe lines, will always give the ſolidity of a parallelipiped whoſe baſe is the product of two of thoſe lines, and whoſe height is the third.

6. If thoſe three lines are equal, the numbers that expreſs them will be equal too, and their product will be a cube.

7. Therefore, the cube of a line, or of a number that ſtands for that line, is had by multiplying that number firſt by itſelf, which will give its ſquare, and then multiplying the ſquare by the ſame number.

8. Thus, the common or linear fathom being ſix foot is cubed firſt by multiplying 6 by 6, whoſe product is 36, the number of ſquare feet in a ſquare fathom, as has been ſhewn in the article of planimetry; then multiply 36 by 6, and the product, 216, is the cube of 6, or the number of cubic feet in a cubic fathom. We ſhall find, in the ſame manner, that the cubit foot contains 1728 cubic inches.

9. *Right or oblique parallelipipeds, whoſe baſes and heights are equal, are equal.*

For, according to the foregoing propoſition, parallelipipeds may be conſidered as made up of an infinite number of parallelograms equal and ſimilar to their baſes; now whether they be right or oblique, they will be made up of as many parallelograms as there are points in their heights; therefore the ſolidity of oblique parallelipipeds will be found in the ſame manner as that of right parallelipipeds, that is to ſay, by multiplying its baſe by its height.

10. *The ſolidity of a right priſm is equal to the product of its baſe by its height.*

For the priſm may be conſidered as made up of an infinite number of ſurfaces equal and ſimilar to the baſe, and laid exactly on one another; now according to this ſuppoſition, there will be as many figures in the priſm as there are points in its height; therefore to have the ſum of all thoſe figures,

figures, that is, the ſolidity of the priſm, you muſt multiply its baſe by its height.

From this propoſition it follows,

Firſt, That priſms, whether right or oblique, having the ſame baſes and heights, are equal, and that therefore the ſolidity of all priſms in general may be found by multiplying their baſe by their height.

Secondly, That as a cylinder may be conſidered as a priſm of an infinite number of ſides, cylinders, whether right or oblique, having the ſame baſes and heights, are equal, and that their ſolidities are to be found in the ſame manner as thoſe of priſms, that is, by multiplying their baſes by their heights.

11. *Right or oblique pyramids, having equal baſes and heights, are equal.*

12. A cone may be conſidered as a pyramid of an infinite number of ſides, thus, *cones right or oblique, having equal baſes and heights, are equal.*

13. *Every pyramid is the third part of a priſm that has the ſame baſe and height as the pyramid.* Now the ſolidity of a priſm is had by multiplying its baſe by its height; therefore to have the ſolidity of a pyramid, you muſt multiply its baſe by the third part of its height.

14. *Every cone is the third part of a cylinder that has the ſame baſe and height as the cone*; ſo that as the ſolidity of a cylinder is had by multiplying its baſe by its height, you muſt for the ſolidity of the cone multiply its baſe into the third part of its height.

15. If the pyramid or cone be truncated, by means of a plane parallel to their baſes, firſt find what their ſolidity would be, if they were whole or entire, then find the ſolidity of the part cut off; then ſubſtract this from the firſt,

and the remainder will be the ſolidity of the truncated pyramid or cone.

It is here taken for granted, that the height of the whole pyramid or cone is known; but this height may be found with exactneſs enough for practice, if the pyramid or cone be not high, by laying two long rules on two ſides of the pyramid or cone. Theſe rules will repreſent the two ſides of theſe ſolids prolonged, and muſt meet in a point, which will be the vertex. From that point drop a perpendicular on the baſe of the part cut off; this perpendicular will be its height; then meaſure the truncated pyramid or cone, according to the method juſt now delivered.

16. If the truncated pyramid or cone are very high, the height of the part cut off may be found in the following manner.

Note, All that is delivered here of a truncated cone is alſo applicable to a truncated pyramid.

Fig. 100. Let ABCD be a truncated cone, ſuppoſe it to be entire or whole, and then its ſides AD, BC, will meet in the point S. The perpendicular SP let down from thence to the baſe will be its axis. From D draw DR alſo perpendicular to the baſe, and theſe two perpendiculars SP, DR, will complete two right angled ſimilar triangles ARD, APS; the ſides AR, RD, of the triangle ARD will be known; for AR is the difference of the radius's DQ and AP, which may be meaſured, and RD is the height of the truncated cone; which may be found by the method of finding an inacceſſible height CD, *fig.* 54. The ſide AP of the triangle APS is alſo given; ſo that comparing the homologous ſides of theſe two ſimilar triangles together, you will find the height of the axis PS by the *rule of three*, in the ſame manner as the height AB was found, *fig.* 55. For the triangles ARD, APS, being ſimilar,

AR:

AR:RD::AP:PS. So that PS being known, take off PQ or RD, the remainder QS will be the height of the axis of the part cut off DSC. For inſtance, if the radius AP be three fathoms, and the radius DQ one, AR will be two; and if RD or PQ be eight fathoms, it will be as 2:8::3: PS, *i.e.* 12; from which, if you ſubſtract RD or PQ, that is, eight fathoms, the remainder will be four fathoms for the height QS.

17. If the cone ſhould be oblique, the two perpendiculars DR, SP, would ſtill complete two right angled ſimilar triangles, by means of which we may come at the knowledge of SQ the height of DSC, the part cut off; this is done by comparing their homologous ſides as above.

18. *A ſphere is two thirds of a cylinder, whoſe baſe is a great circle of the ſphere, and height the diameter of that circle.*

The ſolidity of this cylinder is had by multiplying its baſe into its height, *i. e.* the plane or area of a great circle of the ſphere by its diameter. Now ſince the ſphere is two thirds of this cylinder, you muſt, in order to know its ſolidity, firſt find the area of its great circle, and then multiply this area by two thirds of the diameter, or, if you will, by the whole diameter; but in this caſe the ſolidity of the ſphere will only be two thirds of the product.

For inſtance, if you would find the ſolid contents of the whole earth, firſt get the area of its great circle, by multiplying its circumference (9000 leagues) by half the radius or the fourth part of the diameter (715¾ leagues;) then multiply this area (6441750 ſquare leagues) by the diameter of the earth (2863 leagues) and ſubſtracting from the product (18,442,730,250) you will have the ſolid contents of the whole terreſtrial globe, 12,295,153,500 cubical leagues.

Solids or bodies which differ from thoſe we have given the method of meaſuring may be meaſured by conſidering them as being compoſed of parallelipipeds, priſms, pyramids, &c. according to the form and figure of the bodies; and the ſum of the ſolid contents of theſe bodies will make up the ſolidity of the whole body.

Hollow bodies are meaſured as if they were full, without taking notice of their cavities; then meaſure the cavities alone, and ſubſtracting from the former, what remains will be the ſolidity of the hollow body. As for example, bricklayers work in a well, is meaſured by conſidering the well as being full, and meaſuring it accordingly. Then meaſure the empty part, and ſubſtract it from the former, the remainder will be the meaſure of the bricklayer's work.

Very irregular bodies may be meaſured by putting them into ſome regular veſſel or other, whoſe vacuity may be meaſured. Fill this veſſel up with water, then take out the body whoſe ſolid contents you are ſeeking for. It is evident that there will be a vacuity at the top of the veſſel equal to the capacity or ſolidity of the body taken out; wherefore the ſolidity of this body is had by meaſuring the vacuity in the upper part of the veſſel.

SUP-

SUPPLEMENT,

Containing the properties of tangents, and the meaſure of angles whoſe tops are in the circumference of the circle.

1. *All lines, as* BD, *perpendicular to the radius* CA *at the extremity of it, touches the circle in one ſingle point only.* Fig. 101.

If from the center C of the circle, a line CL be drawn to the line BD, the radius CA being perpendicular to BD, CL, will be oblique to it, and conſequently greater than the perpendicular CA; therefore the point L will be out of the circle. Therefore, *&c.*

Whence it follows, that the tangent BD touches the circle only in a ſingle point A; that if through this point to the center C of the circle, the radius CA be drawn, it will be perpendicular to the tangent BD, and therefore a tangent to a circle may be drawn by raiſing a perpendicular to the radius at its extremity. And laſtly, that if from the point of contact a perpendicular to the tangent be raiſed, it will go through the center of the circle.

The fifth problem of the fourth article, *fig.* 34, may be demonſtrated from this propoſition. For if lines be drawn from the points taken for centers in the line AB, to the points where the line CD touches the arches, theſe lines will be equal, being radius's of equal circles. Further, they will each of them be perpendicular to the line CD by the propoſition we have juſt now demonſtrated; now perpendiculars between parallels, are equal; therefore by the definition of parallels, the lines AB, CD, will be parallel.

2. *If from the center* C *of a circle a perpendicular* CE *be let fall on a chord* AG, *it will divide it into two equal parts in* E; *and being prolonged, it will alſo divide the arch* AFG *which this chord ſubtends, into two equal parts in* F. Fig. 101.

The

The point C is equidiſtant from the points A and G, theſe being in the circumference of the circle of which C is the center; and the line CE being perpendicular to CA, all its points will be equidiſtant from the points G and A. Therefore the point E is the middle point of the line GA; the point F alſo is by the ſame reaſon equidiſtant from the points A and G; therefore it is the middle point of the arch AFG. Therefore, *&c.*

If inſtead of producing the perpendicular CE towards F, it were produced towards the oppoſite arch, it is evident that it will likewiſe cut this arch into two equal parts.

It follows from this propoſition, that if from the center C of a circle, a line CE be drawn which divides the chord AG into two equal parts, it will be perpendicular to the chord AG; and that if a line FE cuts the chord AG perpendicularly into two equal parts, it will paſs through the center of the circle, if it be produced within the circle.

Note here, that the chord AG equally belongs to the two arches AFG, AHG, as it ſubtends them both; but it is uſually conſidered to belong to the leſſer arch, that is, to that which is leſs than the ſemi-circumference, which in this caſe is AFG.

Fig. 101. 3. *An angle, as* BAG, *made by a tangent* BA *and a chord* AG, *is meaſured by half of the arch* AFG, *which the chord ſubtends.*

From the center C draw CF perpendicular to the chord AG, which will divide this chord, together with its arch, into two equal parts in the points E and F; then draw the radius AC, and the triangle CEA will be a rectangle; and therefore the two angles ECA, CAE, taken together, will be equal to one right angle. The radius CA being perpendicular to the tangent BA, the whole angle CAB is right; and therefore the angles EAB, EAC, together, are equal to one right one; now ſince the angle EAC, added to each of theſe

theſe angles ECA, EAB, reſpectively makes a right angle, it follows from thence that theſe two angles are equal. But the angle ECA or FCA is meaſured by the arch AF, half of the arch AG; therefore the angle BAG, which is equal to it, will be meaſured by the ſame arch AF. Therefore, *&c.*

It follows from this propoſition, that the angle GAD made by the chord GA, and the tangent AD, is meaſured by half the arch GHA; for BAG and GAD being equal to two right ones, will be meaſured by half the circumference. Now the angle BAG is meaſured by half the arch GFA; therefore the angle GAD will be meaſured by half of what remains of the circumference, which is the arch GHA.

4. *The angle* GAH, *whoſe top* A *is in the circumference of a circle, is meaſured by half the arch* GH *upon which it ſtands.* Fig. 101.

For let the tangent BAD be drawn, and you will have thoſe three angles, BAG, GAH, HAD, equal to two right ones; they will therefore be meaſured by half of the whole circumference. Now, by the foregoing propoſition, the angle BAG is meaſured by half the arch AFG, and the angle HAD by half the arch AH; therefore there remains for the meaſure of the angle GAH half of the arch GH upon which it ſtands. Therefore, *&c.*

It follows from this propoſition,

Firſt, That all angles whoſe tops are in the circumference of the circle, and which ſtand upon the ſame arch, are equal.

Secondly, That of thoſe angles whoſe tops are in the circumference of the circle, that which ſtands upon an arch leſs than a ſemi-circumference, is acute; that which ſtands upon the circumference, is a right angle; and that which ſtands upon an arch greater than the ſemi-circumference, is obtuſe.

Thirdly,

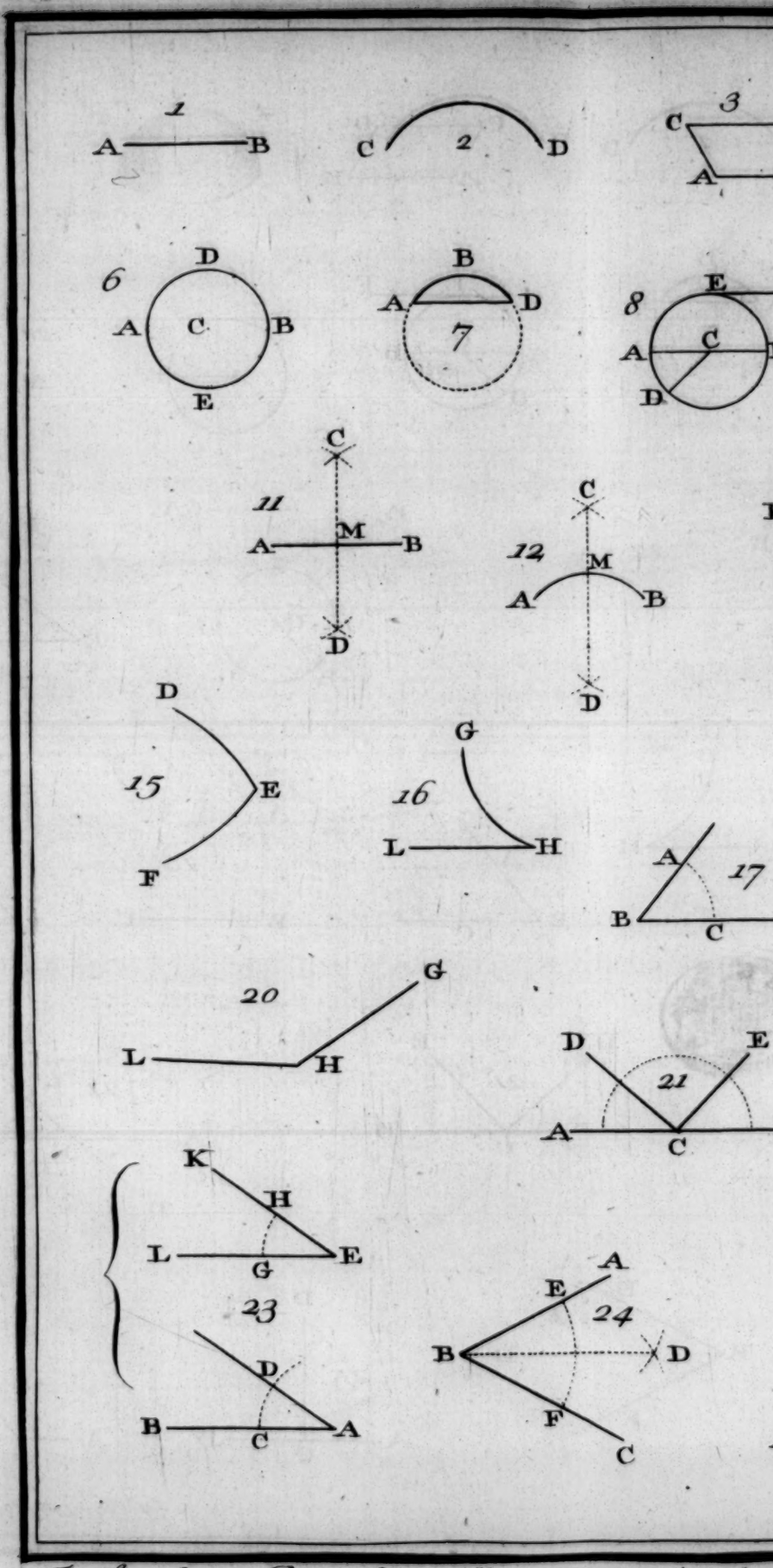
Fig. 101. *Thirdly*, That the angle GCH, whoſe top C is at the center of the circle, is double the angle GAH, whoſe top is at the circumference, and which ſtands upon the ſame arch, for the angle GCH is meaſured by the whole arch GH; and the angle GAH is meaſured by the half of it only.

By the help of this propoſition a perpendicular to a line may be drawn at its extremity without prolonging the line.

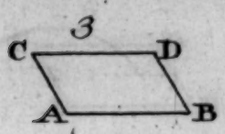
Let AB be the line to which you are to draw a perpen-
Fig. 102. dicular at the point A; take any point C without the line, but ſo as that placing one foot of the compaſſes upon this point, you may extend the other to the point A; then taking C for a center, with the diſtance CA, deſcribe a circle which may cut the line AB in D; then draw a line through C and D which ſhall cut the circle in E, and the line EA will be the perpendicular required. For ſince the line DE paſſes through the center C, it is the diameter of the circle, and cuts it and the circumference into two equal parts; ſo that the angle EAD, whoſe top is in the circumference, ſtands upon the ſemi-circumference; therefore it is a right angle; therefore the line EA is perpendicular to AB.

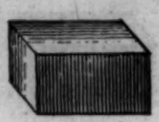
And thus we have laid down in the foregoing ſheets ſuch Elements of Geometry as are anſwerable to the deſign of this ſhort treatiſe.

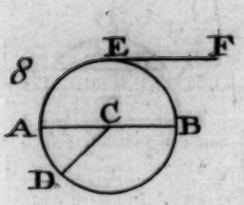
THE

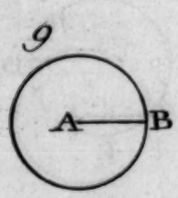


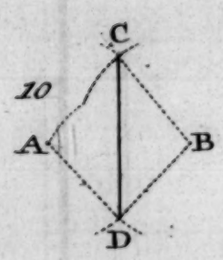
The five Geom. Plates Numb.rs 1 to 5 to be placed a

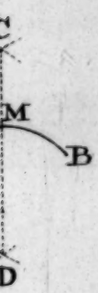


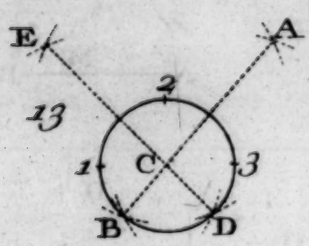


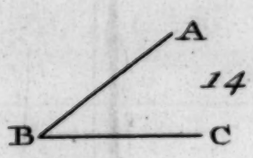


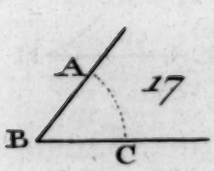


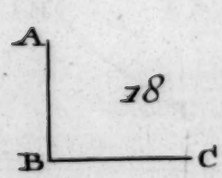


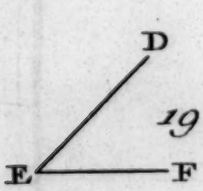


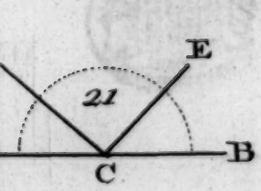


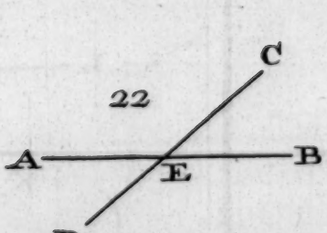


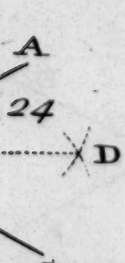


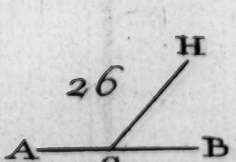












P. Fourdrinier Sculp. 1746.

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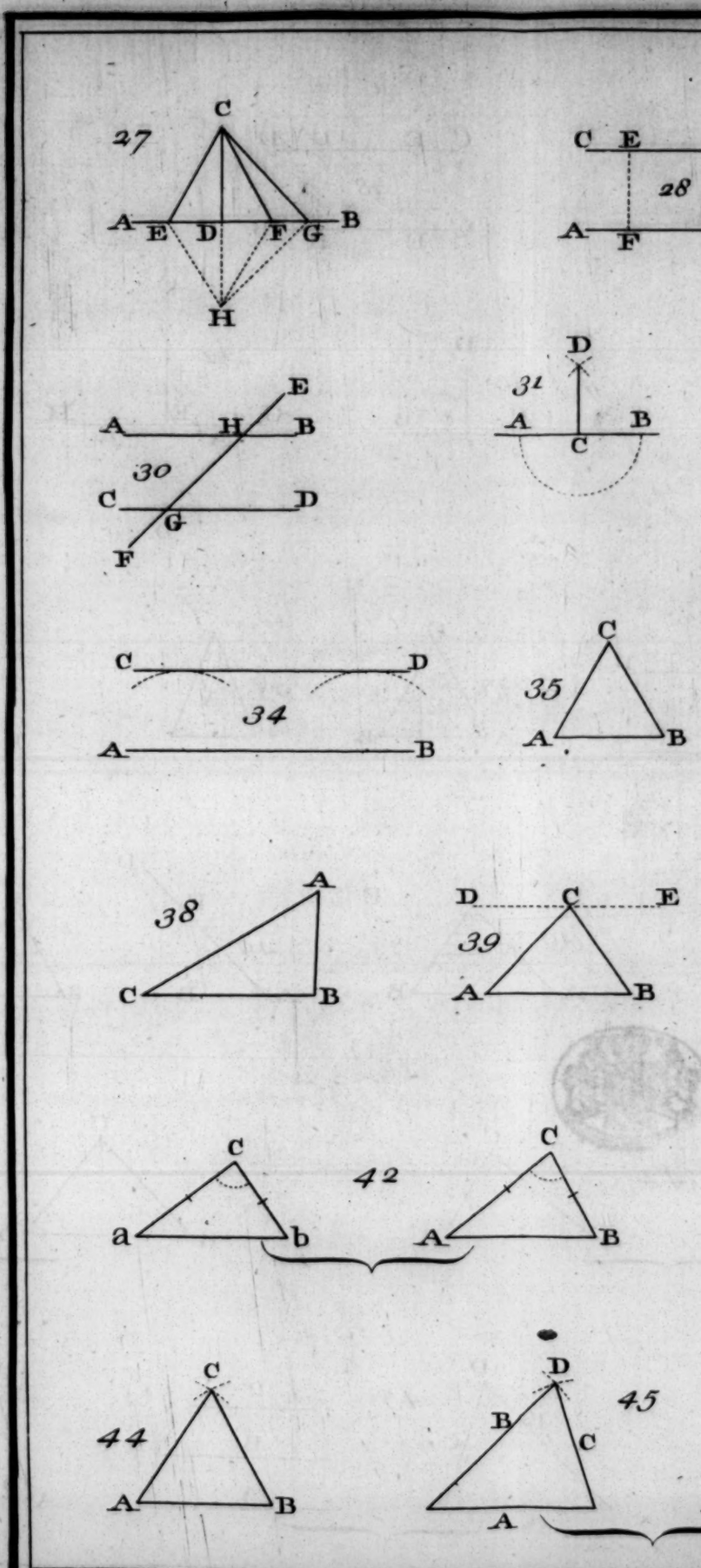
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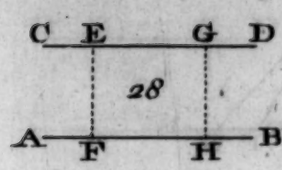
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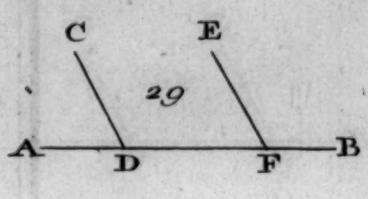
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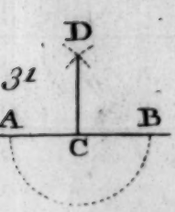
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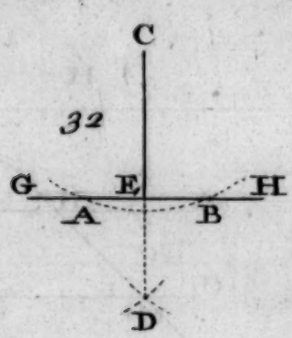
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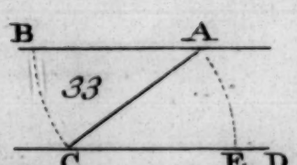
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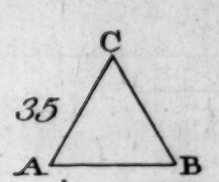
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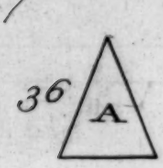
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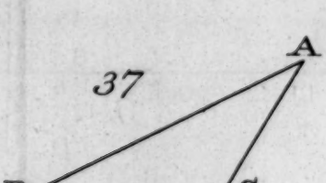
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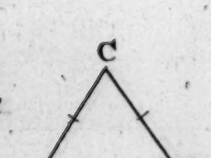
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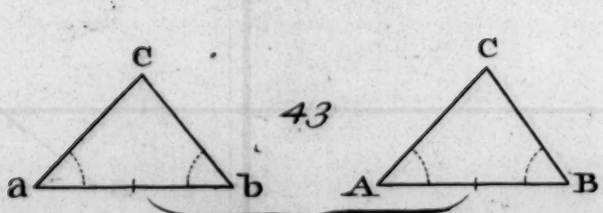
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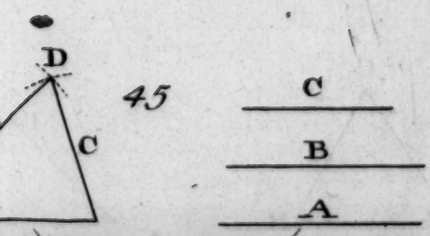
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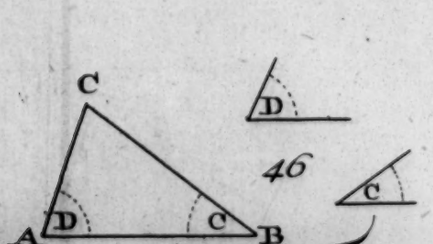
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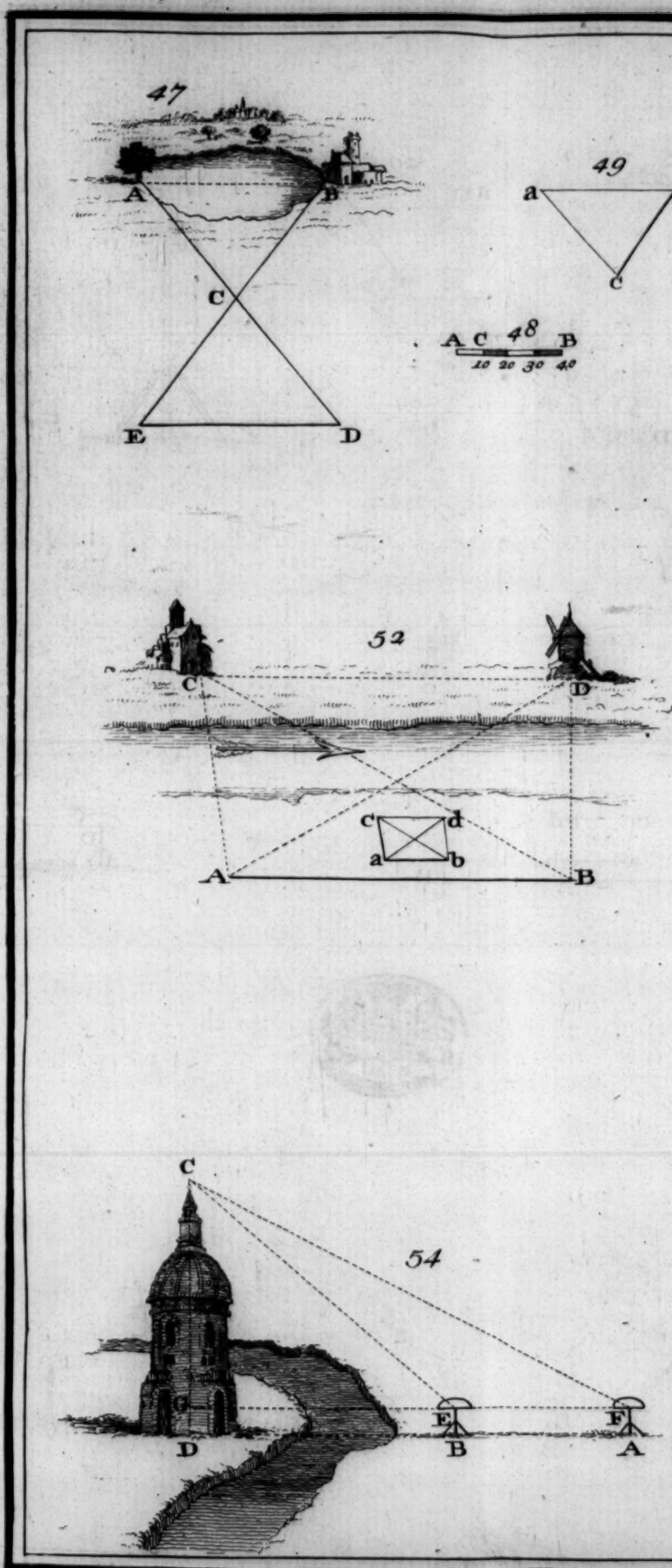
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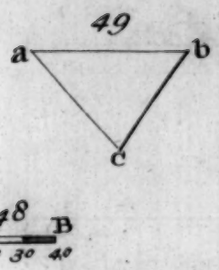
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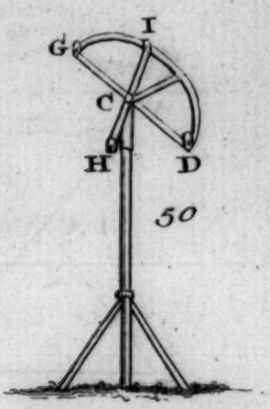
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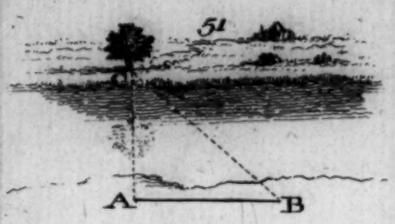
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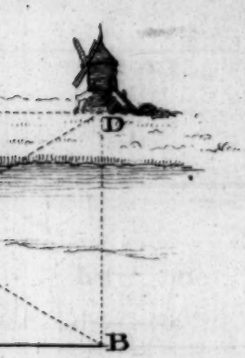
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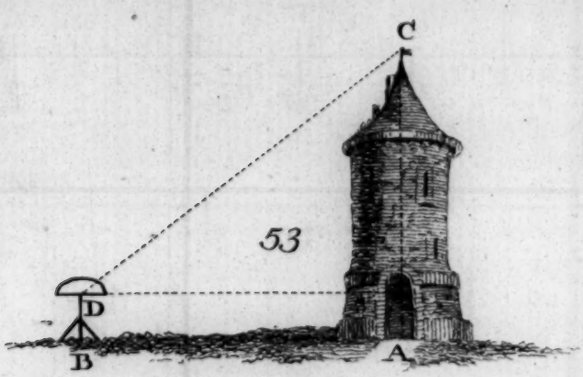
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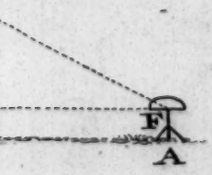
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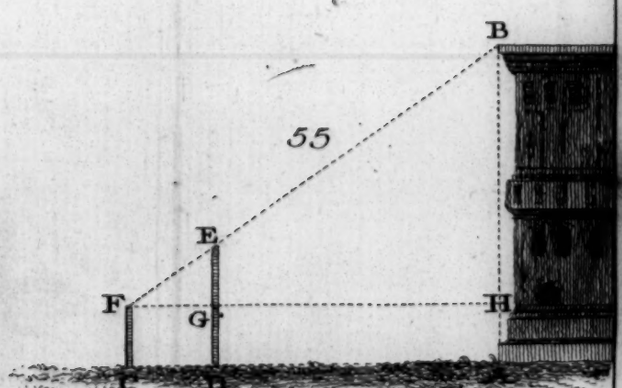
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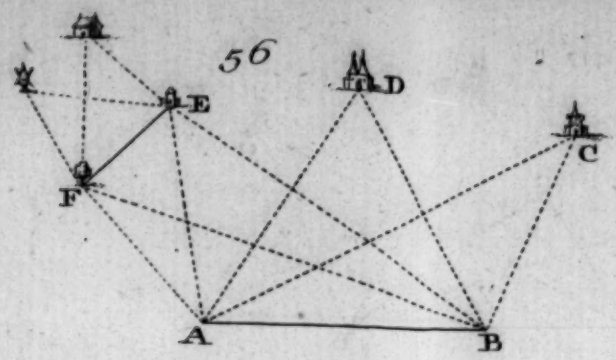
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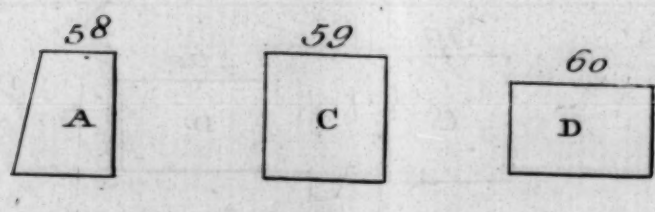
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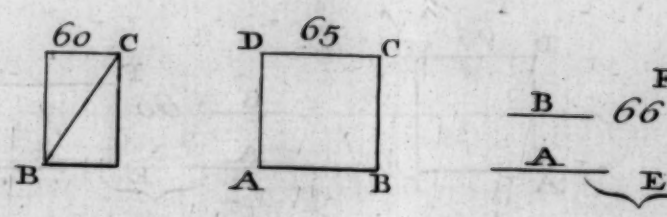
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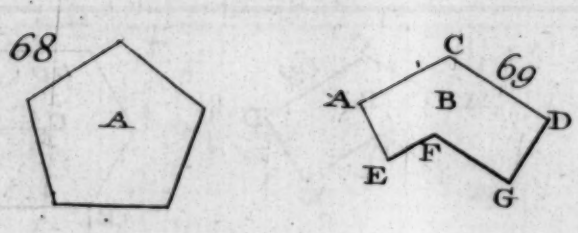
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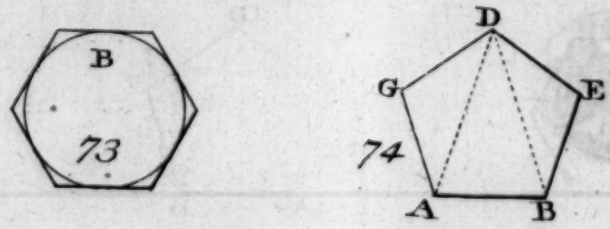
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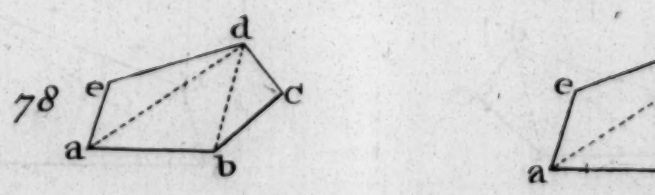
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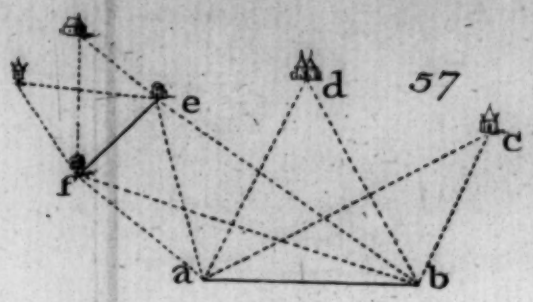
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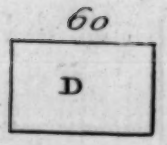
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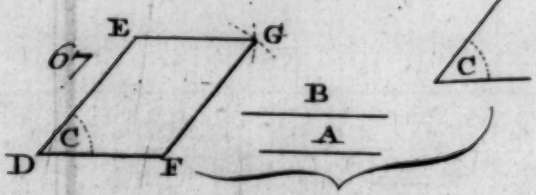
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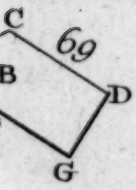
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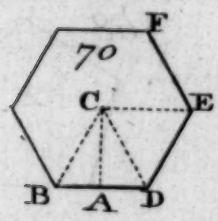
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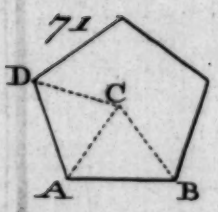
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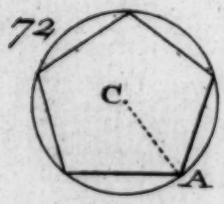
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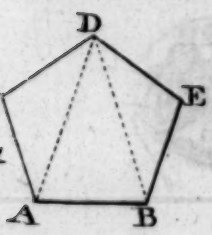
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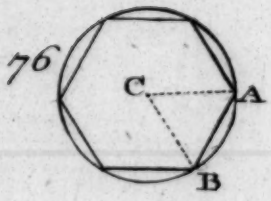
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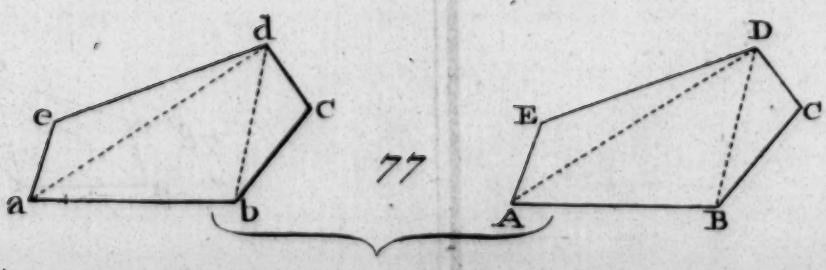
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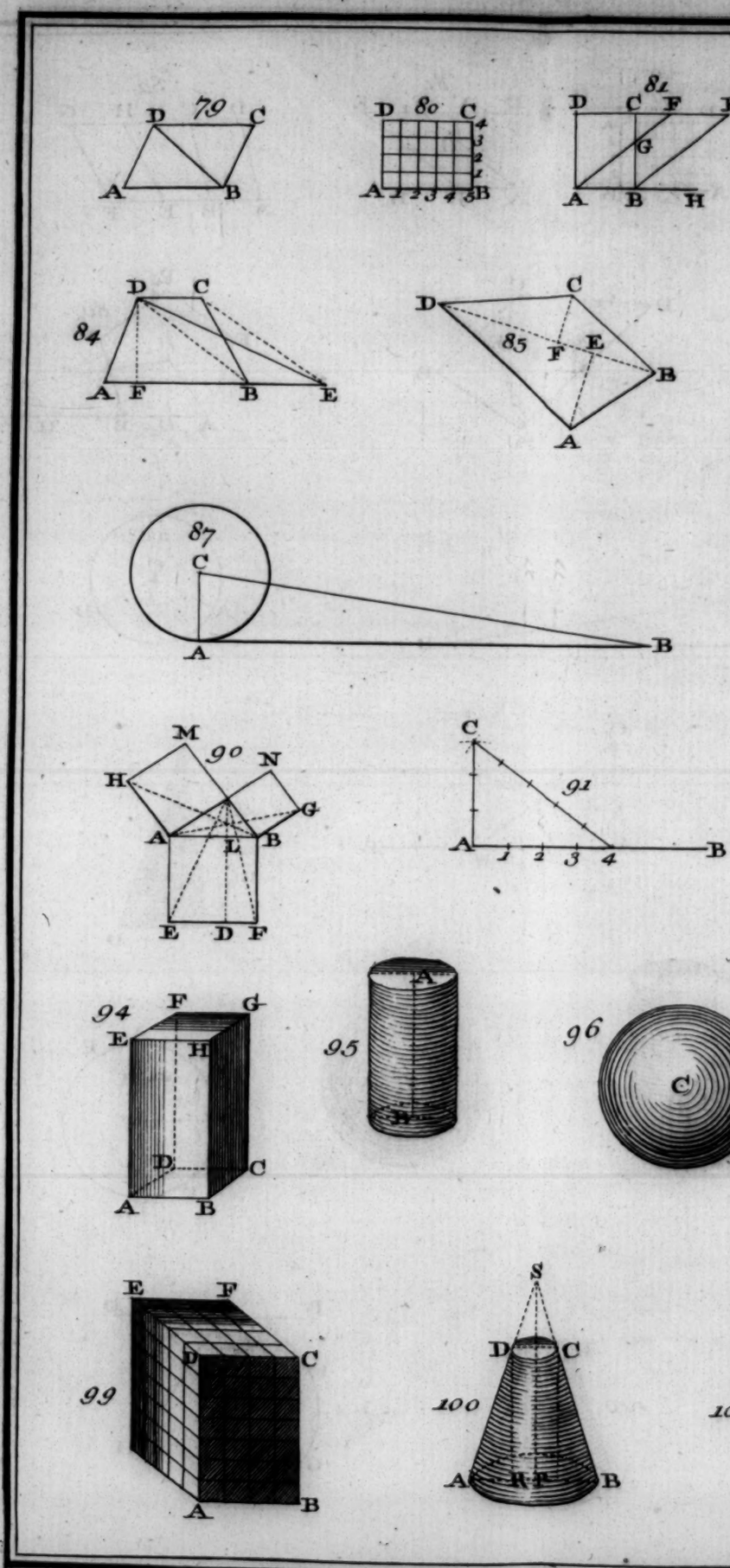
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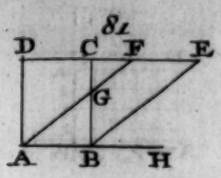
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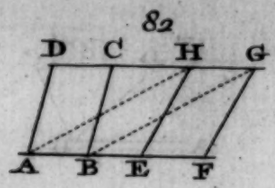
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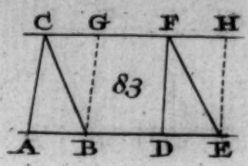
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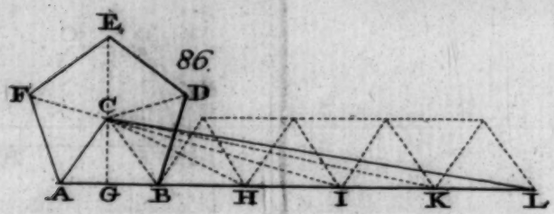
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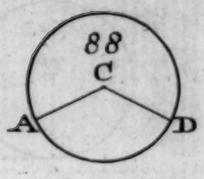
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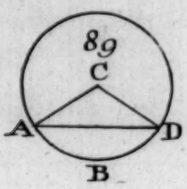
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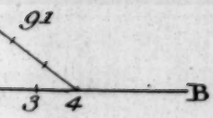
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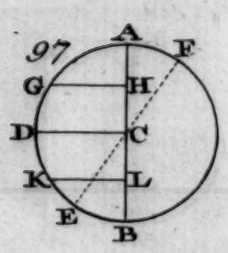
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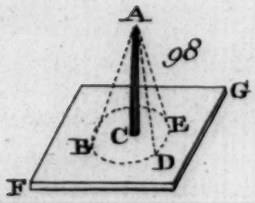
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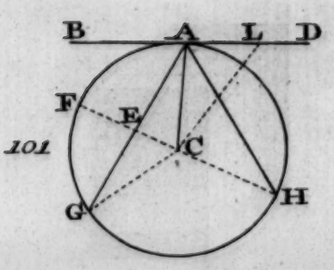
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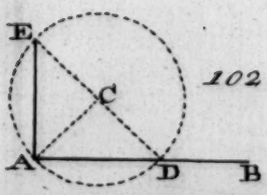
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THE ELEMENTS OF *FORTIFICATION.*

INTRODUCTION.

Concerning the DEFINITIONS, ORIGIN, *and* PROGRESS *of* FORTIFICATION.

FORTIFICATION, taken in its moſt extenſive ſignification, is the art which teaches the *Structure*, *Attack*, and *Defence* of a *Fortreſs*.

The deſign of Fortification is to enable a ſufficient number of men to defend a place they are ſhut up in againſt the attacks of a more powerful enemy.

'Till the invention of cannon, there were no other methods practiſed to ſtrengthen cities, than thoſe of ſurrounding them with walls, round and ſquare towers being raiſed at proper diſtances; but the terrible effects of theſe thundering machines rendered it neceſſary to change the ſtructure of the ancient walls, and add ſo many things thereto, that thoſe changes were thought ſufficient to conſtitute a

new art, which was called *Fortification*, by reaſon of the ſtrength it afforded thoſe in cities or towns to defend themſelves againſt an enemy.

The moſt ſimple idea we can conceive of Fortification in its earlieſt times, is the ſame we are apprized of from travellers concerning the manner in which the *Indians* of ſeveral Nations ſecure their villages and towns, by ſurrounding them with ſtakes and paliſades, to prevent wild beaſts or enemies from ruſhing in amongſt them.

Had all mankind continued living in hutts and caves, theſe fences would have remained without any more improvement than their habitations; but as ſoon as there appeared any buildings of ſtone raiſed with art, ſo ſoon likewiſe a wall ſupplied the place of paliſades.

The beſiegers then were obliged to ſurround the place, and were very careful that nothing ſhould come in or out; thus they patiently waited to effect by famine what art or ſtrength were as yet uncapable of executing. This occaſioned ſieges of ten or twenty years, as are recorded in ancient hiſtories.

But theſe blockades were found out to be too tedious, therefore the beſiegers thought of ſcaling the walls, and likewiſe of ſapping their foundations, for this laſt purpoſe they laid into holes that they had digged under the wall, ſmall piles of wood, very dry, to ſupport it whilſt they were at work, which being ſet on fire, and conſumed, made the wall fall down.

The beſieged then, to hinder their enemies approaching ſo very near to the walls, thought proper to make balconies, which run along the inſide of their wall, juſt at the top, from whence they uſed to let fall great heavy ſtones, to deſtroy thoſe who either attempted to ſcale the walls, or ſap their foundations.

But

Experience afterwards taught the beſieged, that a plain wall was of too weak a defence, and that the only advantage they had above the beſiegers was, that of being raiſed higher from the ground, for when they appeared at the tops of their walls to defend them, they were as much uncovered and expoſed as their enemies; therefore they made *murdreſſes*, to ſhoot at the enemy, and cover themſelves behind the ſpaces that were left betwixt them; but theſe became uſeleſs as ſoon as the enemy had reached the foot of the wall, ſince the ſame ſpaces likewiſe covered him; *Towers* were then thought of to defend the walls and moleſt the enemy, not only in front, but on the ſides. Theſe towers at firſt were ſquare, with one face of them preſented towards the enemy, and two others to defend the wall, the fourth being towards the place was generally left open. The diſtance theſe towers were placed at one from the other was about an arrow's ſhot, or ſomething more. Fig. 1.

This firſt method ſeemed deficient, becauſe the front of the tower A B was not defended from any part of the two others that were near it; this front then was as much without defence as a plain wall; they then built them round; theſe were preferable to the former, becauſe the ſpace betwixt C and D, that remains without defence from the adjacent towers, is not very conſiderable. Beſides, the ſtones they were built with were cut out like wedges, by which contrivance they could better reſiſt the ſhocks of the battering-ram, the machine then made uſe of to overthrow walls. Fig. 2.

All ancient towns and cities are thus fortified, unleſs ſome modern works have been added to them.

There were another ſort of ſquare towers in uſe, one of whoſe angles was preſented towards the field; theſe had the advantage of having the two ſides covered which were Fig. 3.

next the wall, and yet they defended it, as may be ſeen in the figure. It is moſt likely it was this ſort that gave the firſt notion of *Baſtions*, in the beginning called *Bulwarks*, which were not in uſe till about the year 1500.

It ſeems that the ancients, in proceſs of time, were acquainted with all the principles and fundamental rules which are eſtabliſhed in the art of modern Fortification; they could prevent the approaches of an enemy to a town, by overflowing the country; they knew how to make deep ditches, which they ſurrounded with paliſades to prevent an enemy's deſcent; they raiſed heaps of earth behind their walls to withſtand the force of the battering-ram; the ſeveral ingenious inventions they had for throwing of darts and arrows, and even prodigious great ſtones, ſhew that they had acquired a thorough knowledge into the art of war, and may be juſtly eſteemed our maſters therein, eſpecially for the ſeveral artifices and ſtratagems ſo requiſite on many occaſions; what changes we have wrought are accidental, and owing merely to the difference of our arms and theirs. Since the invention of gun-powder, the cannon and mortar, with the leſſer ſort of fire-arms, are introduced inſtead of the *Battering-rams*, *Catapultas*, *Baliſtas*, *Scorpions*, *Javelins*, *Slings*, *Arrows*, *Darts*, &c.

Baſtions are thoſe parts in modern Fortification which ſerve inſtead of towers; they are made conſiderably bigger, that they may be capable of reſiſting ſo much the longer, and that they may contain ſoldiers and cannon enough for the defence of the place; and as the enemy drives his attacks chiefly againſt the baſtion, it muſt be large enough to make intrenchments therein, to prevent his lodging himſelf upon the breach, tho' he had gained it ſword in hand.

Several *Dutch*, *German*, *Italian* and *French* authors have ſince cultivated this art, but it muſt be owned that none

none of them have ſucceeded ſo well as *M. de Vauban*, who has brought it to the perfection we now ſee it has acquired.

Places deſigned to be fortified are either *regular* or *irregular*; *regular* are thoſe whoſe circumference is like unto a regular Polygon, and whoſe ſides do not exceed the length of 200 *fathoms*. *Irregular places* are thoſe, whoſe circumference is irregular, or if it is *regular*, has its ſides longer than 200 *fathoms*, or leſs than 160; theſe meaſures are meant to be applied to the exterior polygon.

From theſe two ſorts of places have riſen two ſorts of Fortification; one which is called regular, and is applicable to the firſt of them; the other which is called *irregular*, and is applicable to places of the ſecond ſort.

Fortification is either *durable*, or *temporary*; *durable* is that which is built with great expence, to continue a long time; ſuch are the uſual Fortifications of cities, *frontier places*, &c. *Temporary Fortification* is that which is erected on ſome emergent occaſion, and only for a little while; ſuch are field-works, caſt up for the ſeizing and maintaining ſome poſt or paſs; alſo thoſe about camps, &c. as *circumvallations*, *countervallations*, *redoubts*, *trenches*, *batteries*, &c.

Fortifications are made on the confines of a country, to ſerve as barriers againſt the invaſions of an enemy, but they ought not to be made but in ſuch places where they become abſolutely neceſſary.

Fortreſſes are diſpoſed into three *lines* or *rates*. Places of the *firſt line* or *rate*, are thoſe whoſe polygon is a ſquare pentagon or hexagon, or ſome equivalent figure.

The *ſecond line* is compoſed of places which are either heptagons, octogons, decagons, or ſomething equivalent.

Places of the *third line* are either endecagons, dodecagons, and upwards, or equivalent; theſe ſerve for the great magazines in time of war.

The

The ſmalleſt places are diſpoſed in the firſt line, becauſe an enemy will not fail beſieging thoſe he meets with firſt; their loſs then is not ſo conſiderable, and their recovery more eaſy.

Places of the firſt and ſecond lines muſt not be at too great a diſtance from each other, elſe the enemy may penetrate without difficulty to thoſe of the third line; and thus the two foremoſt would become entirely uſeleſs.

There are three different parts made uſe of in the drawing of Fortifications upon Paper, *viz.* *Ichnography*, *Orthography*, and *Scenography*.

Ichnography is the plan or repreſentation of the length and breadth of the parts of a fortreſs, conſidered as being levelled to the ground; by this we are at once acquainted with the value of the different lines and angles.

Orthography is the profil or repreſentation of a fortreſs, when any of its works are ſuppoſed to be cut by a plane perpendicular to the horizon, ſo that a perſon may not only ſee their lengths or breadths, but likewiſe their heights and depths.

Scenography is the perſpective view of the parts of a fortreſs, juſt as they would appear in a landſcape.

The *Toiſe* is a meaſure of ſix *French* Feet (*pieds de Roy*) and is uſed in all buildings and fortifications by their engineers; the word *Toiſe*, in the *Engliſh* language, ſignifies *Fathom*: Theſe two meaſures correſpond in the diviſion of the feet, but theſe diviſions being unequal, it is neceſſary to obſerve, That the proportion of the *Yard* as lately fixed by the *Royal Society* at *London*, to the *Half-Toiſe* as fixed by the *Royal Academy* at *Paris*, is as 36 to 38,355: Therefore 76$\frac{3}{4}$ Inches muſt be taken for the length of the *Toiſe* or Fathom mentioned and laid down for the *Scales* of the plans belonging to this treatiſe.

CHAPTER

CHAPTER I.

OF REGULAR FORTIFICATION FOR THE BODY OF THE PLACE.

How to trace the magiſtral line to fortify a ſquare pentagon and hexagon, with an explanation of ſome of the principal lines and angles of a fortreſs.

THERE are two ways to fortify a regular polygon upon paper; the one is called *fortifying within*, and the other *fortifying without*, or outwards.

To fortify within, is to repreſent the baſtions and curtin, within the polygon, given to be fortified, which is then called the exterior polygon.

To fortify without, is to trace the baſtions and curtin, without the polygon, given to be fortified; this polygon is therefore ſaid to be the interior polygon.

Erhard was the firſt who began to fortify within, his method which was very deficient was corrected by the Count *de Pagan*, but was perfected by M. *de Vauban*.

This celebrated author has eſtabliſhed three ſorts of Fortifications, the largeſt of all is from 200 fathoms to 230 or 240 each ſide; this he does not approve of for all the ſides of a place, but only for a long ſide that may be towards the banks of a river, where he always raiſes large outworks. The next ſort he ſuppoſes to have ſides of 180 fathoms, and it is this which is moſt frequently in uſe. The leſſer ſort has the ſides of the polygon (the exterior polygon muſt be always underſtood) of 160 fathoms and under.

For

For all the ſtructures we ſhall lay down in this work, we ſhall conſtantly make uſe of the mean ſort.

Fig. 4. Let the ſquare A B C D be given to be fortified; upon the middle of the ſide A B, draw a *perpendicular* E F towards the center G of the polygon, to which you muſt give the eighth part of the ſide A B. From the points A and B draw thro' the point F, common to them both, the two lines A H, I B, indefinitely. Take two ſevenths of the ſide A B, and carry them from A to K, and from B to L. Set one foot of your compaſſes at K, and open them till the other falls upon the point L; from the point K, as center, and with the interval K L, deſcribe an arch L H, that ſhall interſect the line A H at H; with the ſame extent of your compaſſes, one of their feet being fixed at L, deſcribe likewiſe the arch K I, and the line B I will be interſected at the point I; then join A K I H L B by right lines; repeat this operation for the three other ſides of the ſquare, and you will have performed the whole.

The *magiſtral line* A K I H L B, by which you begin to deſcribe all fortifications, is that which determines the lines and angles of the circumference of the place, and is ſo called becauſe it is the principal. Thoſe lines and angles which in any figure are only dotted, are called the *occult lines* and *angles*, or *lines* and *angles* of *ſtructure*; for tho' they are abſolutely neceſſary for the ſtructure of the works, when the plan is finiſhed they become needleſs, and are effaced to avoid confuſion.

It is always neceſſary to have a *ſcale* for the different figures you trace out. M. *de Vauban* takes the ſide A B of the exterior polygon, which we have juſt above ſaid to contain 180 fathoms.

To divide this *ſcale*, draw at ſome corner of your paper an indefinite line, make *a b* equal to A B, and then

then *a b* will contain 180 fathoms; divide it equally into two parts as at *c*, under which place 90, and 180 under *b*; divide *a c* into three equal parts, *a d*, *d e*, *e c*, each of theſe is worth 30 fathoms; put 30 under *d* and 60 under *e*; divide *a d* into three equal parts, each of which is worth 10 fathoms; then divide the firſt *a f* into two equal parts, each of which will ſtand for 5 fathoms; and laſtly, divide the firſt of theſe two parts *a* 5 into five equal parts, and it gives you ſo many fathoms; thus the ſcale *a b* will be divided into as many parts as are neceſſary for the ſtructure of the plan.

If you would make uſe of this ſcale to fortify the ſquare pentagon, hexagon, &c. take 22 fathoms for the perpendicular E F if your polygon is a ſquare, 25 fathoms for the ſame perpendicular if you fortify a pentagon, and 30 fathoms for the hexagon and other ſuperior polygons. As for the faces A K, B L, give to each of them 50 fathoms in all polygons whatſoever. Towards the end of this ſection we will ſubjoin a table for the more eaſy retaining the value of all thoſe lines which are neceſſary in the ſtructure of any polygon from the ſquare to the dodecagon. Fig. 4, 5, 6.

What we have juſt now laid down ſhews, that the perpendicular E F *is taken for the eighth part of* A B *in the ſquare, the ſeventh part if the polygon is a pentagon, and the ſixth part in the hexagon and all other greater polygons; and that the ſide of the exterior polygon is divided into ſeven equal parts, two of which are taken for each of the faces* A K, B L, *in fortifying any polygon whatſoever.*

Here follows the denomination of the *principal lines* and *angles* peculiar to this art.

The principal lines are

A B, *The ſide of the exterior polygon.*

a b, *The ſide of the interior polygon.*

K I, H L, *The flanc*, ſaid to be a right-angled flanc whenever it is perpendicular to the curtin, and an oblique flanc whenever it makes an obtuſe angle with the line of the curtin.

A K B L, *The faces of the baſtion*, ſo called becauſe they are placed fronting towards the enemy: In ſpeaking of the right and left flancs and faces, you muſt always ſuppoſe yourſelf ſtanding within the fortreſs, looking towards the field. To *flank*, in terms of fortification, ſignifies nothing more than to *defend*. K I, H L, are called *flancs* becauſe they ſerve to defend the faces L B, A K, which are oppoſite to them.

a b, *The petty ſemi-diameter.*

G B, *The great ſemi-diameter.*

b B, *The capital lines*, ſo called becauſe they extend the whole length of the baſtion.

H C, *The line of gorge.*

H b, b c, *The demi-gorges.*

I H, *The curtin.*

I b *The curtin prolonged.*

A H, *The line of defence razant*, becauſe the ſhot from the oppoſite flanc L H razes the face A K.

d B, *The line of defence fichant*, or *line fichant*. Suppoſe the line e B to be the face, which if prolonged would interſect the curtin at d, the ſpace I d in the curtin would be then called a ſecond flanc, becauſe it would defend the face e B. The reaſon why

why the line d B is called *fichant* is, becauſe the flanc that defends the face e B does not raze that face, but plays and fixes its ſhot full againſt it.

The names peculiar to ſome of the angles of fortification are

A G B, *The angle of the Center.*

A B C, *The angle of the exterior polygon.*

L B M, *The angle of the baſtion*, or *flancked angle*, becauſe it is ſeen and defended by the flancs of the oppoſite baſtions.

A F B, *The exterior flanking angle*, or *the angle of the Tenail.*

B I K, *The interior flanking angle*, when there is a ſecond flanc, the interſection of the line fichant upon the curtin forms this angle, as B d I.

H L B, *The angle of the ſhoulder*, ſo called becauſe it covers the ſhoulders of the ſoldiers which are poſted along the flancs.

B I K, *The angle of the flanc.*

B I b, *The diminiſhed angle*, always equal to b A B.

a b C, *The angle of the interior polygon*, which is likewiſe the center of the baſtion.

§ *The Letters* H L B M C *determine the figure of a baſtion, with the proper inclination of its faces and flancs.* Fig. 6.

Theſe are what terms are at preſent uſeful, and ought to become familiar for the further Intelligence of fortifications; all others ſhall be explained as they occur.

Here follows the table, whereby having made your ſcale at pleaſure, you may trace out the magiſtral line of any regular place according to M. *De Vauban*'s method, as we have already practiſed.

	The Square	Pentagon	Hexagon
Exterior ſide	180 *F.*	180 *F.*	180 *F.*
Perpendicular	22 *F.*	25 *F.*	30 *F.*
The Face	50 *F.*	50 *F.*	50 *F.*
Great Semi-Diameter	127 *F.*	152½ *F.*	180 *F.*

The great Semi-Diameter for the

	fa	*ft*
Heptagon	206 :	3
Octogon	234 :	3
Enneagon	262 :	2
Decagon	291 :	0
Endecagon	314 :	0
Dodecagon	346 :	4

We muſt not omit inſerting another table that marks out the dimenſions allowed, not only to the perpendiculars,

lars, faces, flancs and capitals of the half-moons of the three ſorts of fortifications abovementioned, but likewiſe to ſuch ſmall forts that are raiſed in the field to guard a paſs, or upon any other occaſion.

The Dimenſions for Field-Forts							Leſſer Fortification				Mean		Great	
Sides of the Polygons	80	90	100	110	120	130	140	150	160	170	180	190	200	260
Perpendiculars	10	11	12½	15	16	18	20	25	25	28	30	30	25	22
Faces of the Baſtions	22	25	28	30	30	35	40	45	45	48	50	52	55	60
Flancs	7	8	9	10	10	14	16	18	20	22	24	24	24	24
Capitals of Half-moons	25	28	30	35	35	40	45	50	50	52	55	55	60	50

The firſt diviſion contains the number of fathoms to be given to the exterior ſide of the polygons for theſe four ſorts of fortifications, *viz.* for a *field fort* is allowed from 80 to 130 fathom, for the *leſſer fortification* from 140 to 170, for the *mean* ſort from 180 to 190, and for the *Great* from 200 to 260 fathoms.

The ſecond diviſion ſhews the meaſures of the perpendicular, varying according to what is allowed to the exterior ſides: Thus, for a field fort whoſe exterior ſide of the polygon is 80 fathom, the perpendicular is 10 fathom; if the ſide of the polygon is 100 fathom, you muſt give 12½ fathom to the perpendicular. But you muſt obſerve,

1. That the perpendiculars for the field forts have been calculated as the eighth part of the exterior ſide, becauſe theſe ſort of fortreſſes very ſeldom are made above a ſquare.

2. In the leſſer fortification the perpendiculars are the ſeventh part of the exterior ſide, as this ſort is moſtly in uſe for cittadels, which generally are pentagons.

3. In

3. In the mean ſort the ſixth part, if the exterior ſide is rated for the perpendicular, this fortification being practiſed for great places, which are either hexagons, heptagons, or larger polygons.

4. In the greater ſort the eighth part of the exterior ſide is given to the perpendicular, to prevent the flanked angles becoming too acute.

This table is only of uſe for field forts, the leſſer and mean fortifications, whenever the former is made a ſquare, the ſecond pentagonal, and the latter hexagonal or more; under theſe reſtrictions it was calculated; otherwiſe the polygon muſt be fortified according to the common method at firſt laid down.

The great fortification, which is never practiſed but for the long ſide of an irregular polygon, admits of the dimenſions laid down in the table without any Exception.

The third diviſion contains the length of the faces of the baſtion, ranged in proper order; the fourth and fifth the length of the flancs and of the capitals of the half-moons, in proportion to the ſize of the exterior ſides.

This table may ſerve for irregular fortification.

Of the Maxims of Fortification.

THERE are ſome certain maxims eſtabliſhed in the art of fortification, according to which, when a fortreſs is raiſed, there can be but little ſaid againſt its advantages to thoſe who are within.

They who deſire to make any progreſs in this art, ought to be thoroughly acquainted with the moſt general and fundamental principles of it, that they may conceive what has given place for the forms of the different parts of a fortreſs, and account for them; otherwiſe a perſon will never

never be able to diſtinguiſh betwixt a good and a bad ſyſtem.

I.

All the parts of a fortreſs ought to be viewed and flancked on every ſide, that the beſieged may be able to defend all its parts without any obſtacle ariſing from its ſtructure.

This maxim is the fundamental one, and is of the greateſt importance; for was there the leaſt ſpace in the circumference of a fortreſs that was not ſeen and defended by thoſe within, the enemy would drive his attacks againſt that ſpace, and could, without much difficulty, open himſelf an entrance into the town.

II.

Thoſe parts in a fortreſs which flanck others, ought to be ſeen but from thoſe parts they ſerve to flanck.

It is impoſſible to obſerve this maxim ſtrictly, which would render a fortification perfect. Orillions are employed on this occaſion to cover the retired flancs.

III.

Thoſe parts in a fortreſs which flanck ought to have as direct a view as poſſible of thoſe they flanck.

This is ſaid with regard to the inclination of the flanc; we ſhall explain, in a ſection ſeparately by itſelf, the advantages and diſadvantages of flancs.

IV.

The length of the line of defence ought to be proportioned to the ſhot of a musket.

Although in the defence of a fort both cannon and musket are made uſe of, one ought to proportion the line of defence rather to the ſhot of a musket than to that of

a

a cannon; hereby they both become uſeful, otherwiſe the musket proves needleſs, which ought to be the defence moſtly to be depended upon, being not liable to the uncertainty, charges and accidents which attend the uſe of the cannon. Experience has taught us, that a musket carries 150 fathoms, but then the ſhot falls quite dead; the true proportion then is from 120 fathoms to 140 fathoms, or upwards, in caſe of neceſſity even 150, but abſolutely never leſs than 120 fathoms, which is the beſt meaſure for the line of defence, and gives alſo a proper length for the curtin, which ought never to be more than 85 or 88 fathoms, nor leſs than 40.

V.

The line of defence razant ought to terminate juſt at the angle of the flanc, whenever there is no ſecond flanc.

This is intended that the face of the adjacent baſtion may be defended from every point in the flanc razant; for if this line of defence was to cut off part of the flanc razant, that part which would be betwixt the angle of the flanc and the point of the interſection would become quite uſeleſs for the defence of the face of the adjacent baſtion. One cannot commit a greater fault than by not making uſe of the whole length of the flanc for the defence of the face it is deſigned to flanck.

VI.

Great flancs are beſt, as are alſo great demigorges.

By obſerving this maxim the whole baſtion becomes larger, and is capable of containing more artillery and men, ſo that the Defence will be hereby infinitely more vigorous. There is no fixing properly all the parts of a baſtion, becauſe they vary according to the polygons they belong

belong to; however to have ſome fixed notion thereof, it is generally allowed that a flanc ſhould be from 20 to 30 fathoms in length, and the demigorge equal to the flanc, or thereabouts: laſtly, the faces ſhould at leaſt be 40 fathoms, and at moſt 60; but whenever you can give them only 50 it is the moſt advantageous length. Great demigorges are beſt, as they afford more room for intrenchments, when the enemy has made a breach in the baſtion, and is making ready for an aſſault.

VII.

The angle of the baſtion, or the flanked angle, ought at leaſt to be an angle of 60 *degrees.*

We ſhall treat of this maxim in the following ſection.

VIII.

All the expoſed parts of a fortreſs ſhould be able to reſiſt the moſt forcible machines uſed in beſieging.

This is very evident, for if the works deſigned to fortify a place were not ſtrong enough to withſtand the force of the engines of an enemy, he would ſoon be maſter of it, and ſuch a place could not be ſaid to be fortified.

IX.

A fortified place ought to be equally ſtrong in all its parts.

For, if a fortreſs has any part in it weaker than another, the enemy will not fail to attack it, and thoſe other parts which are the ſtrongeſt are of no manner of uſe.

X.

A fortreſs ought to command the country that lieth round about it within cannon ſhot.

When one place is higher than another, it is ſaid to *command* it. The *commandment* is ſaid to be *ſingle*, if the height of one place above another is about 9 feet; it is *double* if there are 18 feet; if 27 feet it is *triple*; and ſo on, always increaſing 9 feet, which is the height of one ſingle commandment.

There are three ſorts of commandments, *viz.* the *commandment in the rear*, the *commandment in the front*, and the *commandment d'enfilade*. When any eminence that commands a work can ſee full in the backs of thoſe who are upon the work, this is the *commandment in the rear*, and the moſt dangerous of the three; when any eminence is directly facing thoſe who are upon the ramparts, it is then ſaid to *command in front*; and laſtly, if it can ſee without interruption the full length of a right line, it is then called a *commandment d'enfilade*.

It is evident that the ramparts of a fortreſs ought to command the country wherein it is ſituated, and not be commanded by it; for this purpoſe all the ground around, within 1000 fathoms, ought to be levelled, this diſtance being the common ſhot of a cannon; within this ſpace there muſt not be allowed any trees, any riſing or hollow grounds that may ſerve to conceal and ſhelter the enemy; if there are any, they muſt be filled up, and the heights muſt be razed, or elſe you muſt ſeize upon them and erect ſome works to defend them, and take other neceſſary precautions which we ſhall mention hereafter.

XI.

The more diſtant the works are from the center of the place, the lower they ought to be.

This is a natural conſequence of the foregoing maxim; for tho' the enemy had made himſelf maſter of any of the

the exterior works, if they are lower than the rampart, the fire from thence hinders him greatly from covering himſelf; whereas were theſe exterior works higher than the rampart, they would ſerve to cover him, and he could likewiſe command the place.

Theſe are the moſt eſſential principles to be obſerved in the ſtructure of fortifications, but it is very difficult to put them in execution; one cannot have the ſame regard for them all, without falling into many inconveniences; and it is in being able to diſcern what is moſt ſuitable according to the occaſions which offer, and in managing things ſo that the works may not be ſaid to be conſiderably contrary to the moſt important maxims, that the whole ſecret and difficulty of fortifications conſiſt.

The three following conſiderations are of no leſs importance than the foregoing *maxims*.

1. *A fortification ſhould be ſo contrived, as that it may be defended by as few men as poſſible; this conſideration, when attended to, ſaves a world of expence.*

2. *That the manner of fortifying ſhould be accommodated to that of attacking*: So that no one manner can be aſſured will always hold, unleſs it is likewiſe aſſured that the manner of beſieging is incapable of being altered; therefore to judge of the perfection of a fortification, the method of beſieging at the time it was built muſt be conſidered.

3. *Regular fortification is always to be preferred before that which is irregular.*

Of the advantages of the flanked angles of baſtions which are right angles, or thereabouts, and the diſadvantages of thoſe flanked angles which are too acute.

LET the angle of the baſtion A B C be a right angle, it has then all poſſible advantages to withſtand the
Fig. 7. ſhock of the enemy's cannon; this ſhall be demonſtrated:

Let the perpendicular D E be ſuppoſed to be the direction in which it is battered, it will reſiſt as much as poſſible according to D F, which being parallel to the face B A, is of a ſufficient length, nor can it be longer; ſo that the reſiſtance being known by the length of the line whereby the body reſiſts, a flanked angle of 90 degrees will have all poſſible ſtrength and reſiſtance.

But it is not always poſſible to make the angle of the baſtion a right angle, and it is approved from 85 to 80, even to 75 degrees. There are ſome polygons, ſuch as the ſquare, and others which are irregular, wherein this angle can never be made greater than 65 degrees.

But ſuch an angle as G H I is to be rejected, being under 60 degrees, as ought to be all other acute angles, for
Fig. 8. the following reaſons:

Let us ſuppoſe K L to be the direction of the battery; draw the line K M; L M is the line of reſiſtance, which is to be computed by the diſtance from L to M; but L M falling upon the oppoſite face, you may ſoon overthrow the angle of the baſtion, and make a very great breach therein.

Thus we ſee that no angle under 60 degrees will ſuffice for the flanked angle, which might become obtuſe without any inconveniency; this renders the gorges of the baſtions larger, and of conſequence the demi-

gorges,

gorges, whoſe advantages are laid down in the remark on maxim VI.

However, formerly they did not approve of baſtions whoſe flanked angles were too obtuſe, as L M N, becauſe they could not be defended by the fire from the curtin, which at preſent is entirely diſapproved by ſome; moreover they are at too great a diſtance from the oppoſite flancs O and P, and the diſtance from M to Q was found too ſmall to allow of making any retrenchments in the baſtions: But the half-moons which are made on the right and left of the curtins re-enter greatly upon the flanked angle, and this ſufficiently repairs other defects. Fig. 9.

Beſides, they are often uſed when you have too long a right line to fortify, and wherever you cannot advance outwards the flanked angle, as upon the ſea-coaſt, the borders of rivers, or upon a mountain, &c. as ſhall be ſhewn when we come to treat of irregular fortification.

Of the advantages and diſadvantages of different inclinations of the flancs.

THE flanc A F, according to the Count *de Pagan*'s method, is perpendicular upon the line of defence; the direction of its fire is the beſt that can be; it is alſo very long, and can hold a great many cannon and men; but hereby the face is too much ſhortened, and it is too much fronting the counter-battery of the enemy. Fig. 10.

The flanc that is perpendicular upon the curtin, as A C, according to Chevalier *de Ville*, is too ſhort, and does not raze or glance well enough along the face of the oppoſite baſtion.

The flanc A D perpendicular upon the face, is according to *Erhard*'s ſyſtem, and is worſe than the former, for it is ſhorter, and can diſcover very little along the face

face I G, which it ought to defend. It covers exceeding well its own cannon, which becomes uſeleſs, and can only ſerve to ruin the oppoſite flanc I B.

M. *de Vauban* has very judiciouſly fixed upon the flanc A E. It makes an angle of 100 degrees with the curtin. It does not diminiſh the proper length of the face, it contains a ſufficient number of ſoldiers and artillery; and it razes directly the face it defends, according to maxim III. nothing more can be deſired upon this head.

What we have hitherto ſaid, is deſigned to render the firſt elements of this art clear and intelligible; we ſhall now proceed to the ſtructure of the rampart and parapet, &c.

How to trace the rampart and parapet.

A FORTIFIED place is always ſurrounded on every acceſſible ſide with a *rampart*, *foſsè*, and *covert way*.

The rampart is a heap of earth raiſed round about a fortreſs; it is intended to cover the buildings within the place, and to raiſe the beſieged as high as is neceſſary to help them to diſcover the lands that lay round about the place; by theſe means, at the approach of an enemy, they fire upon him at as great a diſtance as their arms will carry.

The ordinary height of the rampart is about 3 fathoms above the horizontal line, more or leſs, according to its ſituation with reſpect to the ground it ſtands upon, and the places which are without the fortreſs, and might command it. It is a fault of the utmoſt conſequence to raiſe the rampart too high, for thereby it is quite diſcovered to the enemy's view, who can eaſily ruin it; moreover the expences become more chargeable.

The

The breadth of the rampart at bottom is either 12, 13, 14, or even 15 fathoms, when there is no ſtone or brick-work. In theſe breadths are included the *talus*, this diminiſhes the breadth upwards, which cannot well be fixed before you know the quality of the earth you are to make uſe of: The *talus* ſignifies that declivity or inclination that is allowed to works of earth or maſonry, the better to ſupport themſelves; and the worſe the earth is, the more ſloping they ought to be.

The declivity of the rampart towards the place is called the *interior talus*, and is generally once and half the height of the rampart.

The *eſcarp* or *exterior talus* is the declivity of the rampart and other works towards the field, which muſt never be ſloping enough for the enemy to come up it without great difficulty.

The *parapet* is a maſs of earth raiſed upon the exterior border of the rampart; it ſerves to cover the cannon and ſoldiers which are placed upon the rampart for the defence of the place; it is about 3 fathoms thick, and one in height. At the foot of the parapet, towards the place, is made a *banquet* or little bank; it is deſigned for a ſtep to raiſe the men, that they may ſee over the parapet to fire upon the enemy, for which reaſon alſo the top or ſummit of the parapet is made to go ſloping towards the *outworks*; this is called the *ſuperior talus* of the parapet.

The upper part of the rampart that remains clear, after the parapet has been raiſed, is called the *terre plein* of the rampart, and upon it the ſoldiers and cannon are placed which ſerve to defend the fortreſs.

The rampart and parapet are generally ſuſtained on their exterior ſides by a wall of brick or ſtone that is raiſed the full height, three quarters, or only half, and whoſe foun-

dation

dation is lower than the bottom of the ditch or *foſsè*, but its talus begins at the bottom of the *foſsè*. The rampart is ſaid to be lined when it is ſupported by a wall, and the wall is called the *lining*. There are ſome earths which need no other lining than turf, ſuch as grey clay and ſlimy earth, which anſwer exceeding well in making of ramparts, becauſe they can reſiſt the incoveniences of heat and rain, and ſupport themſelves without being liable to crumble away; but then the firſt diſcharges of the enemy's cannon beat them down prodigiouſly, and facilitates greatly the mounting of the breach, eſpecially if the foſsè is dry, ſo that the beſieged are obliged to capitulate as ſoon as they have loſt the covert way, for fear of being taken by aſſault; theſe, and other apparent diſadvantages, are ſufficient to oblige one to line the works of a fortreſs that is of any conſequence.

Having deſcribed your polygon at pleaſure, and the ſcale thereof as we have directed in a foregoing ſection, proceed as follows. Fig. 11.

1. At the diſtance of 3 fathoms from the magiſtral line, and within the polygon, draw a line parallel thereto, and the ſpace betwixt theſe two lines will expreſs the breadth of the parapet.

2. At ſix fathoms diſtant from the interior line, draw another parallel, and this laſt line will fix the interior ſide of the rampart, and likewiſe the breadth of the *terre plein*.

3. At 4 fathoms and a half diſtant from this laſt line, draw another parallel, and the ſpace betwixt theſe two innermoſt parallels will expreſs the interior talus of the rampart.

4. At 5 or 6 feet diſtant from the magiſtral line, you may draw on the outſide a ſmall fine line, which is deſigned

deſigned to deſcribe the talus of the wall; and upon the *terre plein* of the rampart, hard by the parapet, at 3 feet diſtant therefrom, draw another very fine line, which will expreſs the banquet.

If the plan is too ſmall, theſe two laſt-mentioned lines for the talus of the wall and the banquet are omitted, but they are underſtood.

Whenever the rampart is made to run parallel to the flancs and faces of the baſtion, as z z z z, there is a ſpace left in the middle of the baſtion, and then the baſtion is ſaid to be *hollow*. It is in theſe ſpaces that are placed the magazines for powder and ſtores. Fig. 11.

When the rampart is not drawn parallel to the flancs and faces of the baſtion, but that it breaks off juſt before the gorge of the baſtion, there is no ſpace left in the baſtion, and it is then called a *full baſtion*.

'Tis in full baſtions that are raiſed *cavaliers*, which are nothing elſe but other baſtions raiſed upon the firſt, and of the ſame form. Sometimes they are lined, and have their parapet like other works. Their height above the baſtions is fixed according to the places they are to command. The parapet of their flancs is parallel to the parapet of the baſtion, and is deſcribed at 4 fathoms from it. The parapet of the faces of their faces is within 3 fathoms from the parapet of the baſtion, and is parallel thereto. Underneath theſe cavaliers, as occaſion requires, are made *ſouterreins*, which are vaulted, and run from the gorge of the baſtion to the flanked angle; they ſerve as very ſafe magazines for the ſtores, ammunition, and as a retreat for the ſoldiers in time of a ſiege; and in theſe ſubterranean vaults are made ovens for baking the bread for the gariſon; there is no danger of the bombs ever penetrating therein, for beſides their being vaulted, Fig. 11.

they have that prodigious heap of earth raiſed upon them, which ſerves for the ſtructure of the cavalier itſelf.

When a cavalier is raiſed in the manner we have juſt now laid down, it is deſigned to ſcour the field and command the enemy's batteries. Sometimes the figure of a cavalier is round, or ſquare, *&c.* and then 'tis made to cover ſome part in the place that the enemy could batter, either in the front or rear.

How to deſcribe in a plan the embraſures and barbet batteries.

THE openings made in the parapet for the firing of the cannon are called *embraſures.* They are cut downwards in the parapet, within three feet of the terre-plein of the rampart, and have three different breadths; the firſt breadth, A B, is towards the place, and is 2½ feet; the
Fig. 12. ſecond, C D, is one foot beyond the firſt, and is two feet; the third breadth, N M, which is outwards, is nine feet. That part of the parapet which remains entire betwixt two embraſures is called a *merlon.* The bottom of the embraſures muſt have the ſame ſlope as the ſuperior talus of the parapet, that the cannon may readily be fired into the covert way.

To deſcribe embraſures upon paper, divide the line whereon they are to be deſcribed into parts of three fathoms each. Let the given line E F be nine fathoms, make the interſections at P and Q, and the whole length will be divided into three equal parts. At theſe points of diviſions, P and Q, raiſe the perpendiculars P S, Q R; then, according to the meaſures juſt mentioned, ſet off Q I, Q A, Q B, I C, I D, R N, R M, not forgetting to draw the dotted Line T I V parallel to E F, and by right lines,

lines, as the figure plainly ſhews, join A C, C N, B D, D M, to complete the plan of an embraſure.

Upon the parapet of a work belonging to a ſmall plan, the embraſures are deſcribed only by ſmall iſoſceles triangles, ſet off at the given diſtances one from another, and whoſe baſes fall upon the magiſtral line.

If the flanc is a concave flanc, which ſhall be explained very ſhortly, the firſt embraſure next the retreat of the curtin ought to fire directly in the covert way, and the one next the reverſe of the orillon ought to defend the breach that the enemy might have made in the face of the oppoſite baſtion.

Barbet batteries are platforms raiſed at the flanked angle of a baſtion, or of any outwork about four feet higher than the terre-plein, ſo that the cannon may be juſt high enough to fire over the parapet. The *French* have named this ſort of batteries, *batteries en barbe*, or *en barbette*, becauſe the ball in going out of the cannon ſhaves the graſs from the ſuperior talus of the parapet. They are of great advantage for the firſt days of a ſiege, when the beſiegers are yet at a diſtance from the place, but they are rendered unſerviceable as ſoon as the enemy has brought his batteries in readineſs to play.

For the ſtructure of the barbet batteries; their length is from 9, 12, to 18 fathoms, meaſured off upon the faces of the baſtion from the flanked angles; and their breadth is 3 fathoms, and is drawn parallel to the interior ſide of the parapet; at each end they have an eaſy aſcent 12 feet broad, and whoſe talus is ſix times its height. This is the general rule for the talus of all aſcents in works of fortification.

The earth their platform is made of muſt be well beaten down, and raiſed within 2½ feet to the top of the parapet, and afterwards muſt be covered with oaken planks.

There is a platform for a barbet battery deſcribed at the
Fig. 11. flanked angle A of the baſtion H G A, *&c.*

To deſcribe the concave flanc with its orillon.

THE flanc being the moſt eſſential part in the whole circumference of a fortreſs, it has always been judged proper to increaſe, as much as poſſible, its defence and ſolidity, and to hide it from the enemy's view. Every author has attempted to conceive ſomething that might anſwer theſe three intentions. M. *de Vauban*, whoſe con-
Fig. 13. ſtruction we ſhall here lay down, has, after the manner of the *Italians* who firſt invented it, made part of the flanc concave which is covered by another part that is rendered convex; a flanc thus deſcribed is called a *covert flanc*, or a *flanc concave with orillon.*

Having drawn the magiſtral line of a fortification as we have before laid down,

1. Divide the flanc C D into three equal parts.

2. Let C I be divided into two equal parts, and on the point of interſection raiſe within the baſtion the indefinite perpendicular O K, and at C, the extremity of the face, raiſe another perpendicular to that face, as C K, to interſect the firſt at the point K; from this point K as center, and with the interval K C, deſcribe the arch C I, which is the convex part of the flanc, and is called the *orillon.*

3. From the flanked angle of the oppoſite baſtion draw the right line A I H, give to I H five fathoms; this part is called the *retreat*, *briſure*, or *reverſe of the orillon.* Pro-

long

long the line of defence A D within the baſtion, and make D G equal to I H; then make the equilateral triangle G L H, and from the point L as center deſcribe the concave flanc G P H.

The convexity of the orillon may be deſcribed by taking C I for the diameter.

The fire of the cannon placed next to the reverſe of the orillon, which is entirely out of the enemy's ſight, can only be employed to annoy them in the paſſage of the foſsè; this greatly diſturbs that part of the attack, and deſtroys the miner, to the no ſmall advantage of the beſieged.

The interior ſide of the parapet of the concave flanc is deſcribed circularly from the point L, by adding three fathoms to the interval L H; in the ſame manner, by taking the proper meaſures, are deſcribed the terre plein, and talus of the rampart.

The parapet of the orillon is drawn in a right line at the diſtance of three fathoms inwardly from the line C I, and parallel to it.

The reverſe I H of the orillon being covered by the parapet of the face of the baſtion, has no occaſion for another. In this part are made poſterns for the ſoldiers to deſcend into the foſsè, and from thence to go to the different outworks.

Some authors have deſcribed the orillon ſquare as at E; but this not being ſo ſtrong as the round one, is to be rejected.

The upper and lower flanc, likewiſe called the *caſemate*, as deſcribed by ſome authors, is now out of uſe; we ſhall have occaſion to ſpeak of them in treating of *the ſyſtems of different authors*.

To

To deſcribe the foſsè and covert way with the glacis.

Fig. 11. TO deſcribe the foſsè, take with your compaſſes 18 or 20 fathoms upon the ſcale, and with that interval from the flanked angles A and B deſcribe the two arches C D, F E; then from the angles of the ſhoulder draw the lines L M E and G M C, tangents to the two arches at the points C and E; the interſection of theſe lines at M will form the re-entering angle of the counterſcarp. In this manner you may deſcribe the foſsè for each front of the fortification. It is proper to obſerve, that by thus deſcribing the foſsè, there is no part of it but is ſeen and defended by the flancs. If the line of the counterſcarp E M, when prolonged to L, did not coincide with the angle of the ſhoulder at the point L, but was drawn in direction with a point of the flank three or four fathoms nearer towards the curtin, that ſpace of the flanc would become uſeleſs for the defence of the foſsè and face of the oppoſite baſtion, and thereby you would diminiſh the fire of the flanc, and without any juſt reaſon.

Fig. 14. Was the counterſcarp to be deſcribed parallel to the magiſtral line, it is evident that the flancs A B, C D, could not defend the foſsè of the faces D E, F A, becauſe that part of the counterſcarp G H I K would prevent its being diſcovered. Hence it follows that this manner is abſurd, and that the foſsè of the curtin muſt be more ſpacious than the foſsè of the faces, that the fire of the flancs may not be obſtructed.

It might be thought that there could ariſe no diſadvantages by making the foſsès of a fortreſs very broad and deep, becauſe the beſiegers would meet with more difficulty in their paſſage to the works of the place. But the diſadvantages

diſadvantages of ſuch a ſyſtem would prove real, and the benefits only imaginary; for a foſsè too broad would diſcover the foot of the rampart, and a foſsè too deep, if dry, could not be defended by the cannon of the flancs, which never could ſcour the bottom of it. In the raiſing of a fortreſs, their depth and breadth are calculated according to the quantity of earth that is neceſſary for the rampart, cavaliers, *&c.* but the breadth muſt always be determined ſo, that one may always diſcover the brink of the counterſcarp notwithſtanding the thickneſs of the parapet, which would be impoſſible if it was made too narrow. Its depth muſt always be more than the height of a tall man, therefore it never can be allowed but upwards of ſeven feet. In this treatiſe, when we come to deſcribe the profil of a fortreſs, we ſhall make the depth of the foſsè when dry equal to the height of the rampart, and if wet 12 feet deep.

Some authors have imagined to make in the middle of the great dry foſsè a ſmall ditch, broad and deep, called *cunette* or *cuvette*; it ſerves for a drain to the great one; it ought always to be filled with water, and contrived ſo as to afford no ſhelter or cover to the beſiegers. Fig. 11.

The counterſcarp or exterior border of the foſsè being deſcribed, we proceed next to the *covert way*, and deſcribe it as follows:

1. At five fathoms diſtance of the counterſcarp draw a line parallel thereto; this will expreſs the interior ſide of the parapet of the covert way, and will determine its breadth.

2. At all the re-entering angles of the parapet of the covert ways as at P*, you muſt deſcribe the *places of arms*,

* All re-entering angles in fortification which are not directly flanked, or ſeen from any other work, are called *dead angles*.

arms, therefore make P S and P T 10 or 15 fathoms by your ſcale; theſe two intervals are called the demigorges of the places of arms, and are only occult lines; then from the points S and T, with an interval from 12 to 20 fathoms, deſcribe two arches to interſect each other as at V; then join V S, V T, and the place of arms is formed. The lines V S and V T give the faces of the places of arms. Draw the line for the banquet of the covert way as you have done for that of the parapet of the body of the place.

To fix the breadth of the parapet of the covert way, make X Y X Z parallel to P R, P Q, at the diſtance of 20 or 25 fathoms, the ſpace therein contained is called the *glacis*. At the re-entering angles of the glacis, juſt before the place of arms, muſt be drawn the ſaillant angle as at *b*, therefore make X *a* and X *c* equal to 20 fathoms, and from the points *a* and *c*, with an interval of 20 fathoms, deſcribe two arches for an interſection at *b*, and join *a b*, *b c*, by right lines; then to complete the whole, join all the angles of the glacis with thoſe of the covert way, Q Z, S *c*, V *b*, T *a*, R Y, &c. as the figure ſhews; hereby you will repreſent the ridges and gutters of the glacis.

To deſcribe the tenail and caponiere.

THE *tenail* is a work whoſe ſtructure ariſes from the lines of defence, and is made juſt before the curtin; it is not raiſed above the horizontal line, and ſometimes even a foot and a half, or two feet lower; it is covered by a parapet with one or two banquets.

The tenail ſerves to augment the defence of the foſsè. Fig. 15. The fire of the muſquetry from thence is more dangerous than that of the flancs of the place, being more razant,

and

and nearer to the enemy. Sometimes a tenail is made with flancs, as the figure I N O Q P K. M. *de Vauban*, who invented the work, having at firſt brought into practice a tenail with flancs, afterwards gave the preference to a ſimple tenail, becauſe, as will be ſeen hereafter, theſe flancs could eaſily be enfiladed from the ramparts of the half-moon, which inconvenience is avoided in the ſingle tenail, for the ſtructure of a tenail with flancs.

1. Draw the line G H, parallel to the curtin R S, at the diſtance of three fathoms.

2. At the diſtance of five fathoms from the flancs R E, S F, and parallel to them, draw the lines G I, H K.

3. Draw the lines of defence A S, B R, and from the point M of the flanking angle ſet off on both ſides M N, M P, each equal to the half of the lines M I, M K; then from the points N and P let fall the two perpendiculars N O, P Q, upon the lines of defence B R, A S; theſe perpendiculars are for the flancs of the tenail, and the lines I N, P K, will give the faces: join O Q together to have the curtin of the tenail.

4. The parapet of the tenail is made three fathoms thick, and is drawn parallel to the magiſtral line I N O Q P K. The terre plein is allowed ſix fathoms at the faces and flanks, and only three at the curtin. The banquet is the ſame as that of the parapet of the body of the places; there are generally two at the faces and flancs.

All tenails muſt have a ſmall foſsè cut in the middle of them for to admit of a communication from the body of the place to the caponiere and covert way, and a bridge that joins the two parts of the tenail to paſs from one to the other.

The faces of a tenail with flancs may be of different lengths, according to the ſize of the curtin of the place;

but the flancs are never to be allowed leſs than eight or ten fathoms.

If the breadth contained betwixt the two parallels G H, and the curtin of the tenail O Q, was leſs than ſix fathoms, begin to trace a parallel three fathoms diſtant from the line G H, for the terre plein of the curtain of the tenail; then three fathoms beyond it draw another parallel for the interior ſide of the parapet, and at the ſame diſtance deſcribe the exterior border of the parapet, or the magiſtral line of the curtin of the tenail, which interſecting the flancs N O, P Q, at the points O and Q, will determine the length of thoſe flancs; if they are not found of the dimenſions above given, the whole work is to be rejected, and only a ſimple tenail is to be admitted.

What gave the notion of a tenail with flancs, was the falſe bray formerly practiſed. The magiſtral line of it was ſet off at ſix fathoms diſtance from the magiſtral line of the body of the place, and was drawn parallel to the faces, flancs, and curtin of the place, quite ſurrounding it. In this ſpace of ſix fathoms was included the breadth of the parapet and banquet. Some only deſcribed the falſe bray at the curtin and flancs.

The narrow ſpace of ſix fathoms allow'd to the breadth of falſe brays, which were not ſeparated by any foſsès from the body of the place, obliged the ſoldiers in the time of a ſiege ſoon to quit it, for the ruins of the body of the place immediately choked it up, and rendered it of no uſe; for this reaſon M. *de Vauban* condemned it, and introduced the tenail, which being ſeparated by a foſsè from the body of the place, cannot be liable to the ſame diſadvantages.

To deſcribe a ſimple or ſingle tenail.

BEGIN as for the tenail, with flancs to make D C parallel to the curtin A B, at three fathoms diſtance; then draw the lines of defence O B, P A; afterwards make D E, C F, parallel to the flancs A G, B H, leaving a ſpace of five fathoms; make the breadth of the parapet with the banquet as already laid down, and its interior ſide parallel to the magiſtral line E M F, and draw K V, V N, parallel to the interior ſide, and five fathoms nearer to the body of the place, for the breadth allowed to the terre plein of this tenail, which is deſcribed by the figure K E M F N V. The little foſsè muſt be made, as in the former, at the point M, to divide the tenail aſunder. Fig. 16.

Whenever the lines K X, N Y, which determine the terre plein of the tenail, fall upon the line D C at the points X and Y, the middle part of the tenail R S is made parallel to the line X Y, or to the curtin of the place A B. This part is determined by drawing a parallel to the line X Y at three fathoms diſtance, to make the terre plein of the tenail before the curtin; and laſtly, to this parallel another at the ſame diſtance to determine the thickneſs of the parapet in that part; this laſt parallel will give the exterior ſide R S of the parapet, which is determined by the interſection of the lines of E M, M F, at the points R and S. Fig. 17.

The ſtructure of the caponiere.

TENAILS are ſeldom made but where the foſsès are filled with water; and whenever they are deſigned to be raiſed in dry foſsès, caponieres muſt be added.

Fig. 18. A caponiere is nothing elſe than a double covert way 12 or 15 feet broad, made acroſs the bottom of the foſsè, from the middle of the curtin to the oppoſite re-entering angle of the counterſcarp; on either ſide it is paliſaded, and its parapet, which is only raiſed three feet above the level of the bottom of the foſsè, is made to loſe itſelf in an inſenſible ſlope like a glacis, at the diſtance of 10 or 12 fathoms from its interior ſide; its terre plein is ſunk three feet deep, ſo that the whole height of the parapet is ſix feet. There is alſo a banquet, as in the covert way.

For the ſtructure of the caponiere, draw the lines of defence E H, G F, to have the flanking angle C B D, and from the angular point B to the re-entering angle A of the counterſcarp draw the right line B A, and on each ſide make, at the diſtance of ſix or ſeven feet, the two parallels, as in the figure; theſe lines falling on one ſide upon the lines of defence, and on the other upon the counterſcarp, will fix the length of the caponiere; laſtly, to finiſh it, make its banquets and the exterior borders of its glacis according to the meaſures juſt now mentioned.

Wherever there is a caponiere, there is generally made a ſingle tenail, O B P, in the bottom of the foſsè, having a parapet like that of the caponiere, and is deſcribed by the lines of defence O B, B P, with a glacis of 10 or 12 fathoms broad.

The principal uſe of the caponiere is to render the beſiegers paſſage of the foſsè more dangerous, and cover the beſieged in their paſſage to and from the covert way. That the ſoldiers may not be diſcover'd as they come out of the caponiere, the re-entering angle of the counterſcarp is cut off, this is done by making A L and A K each eight or ten fathoms, and drawing the right line L K.

Sometimes

Sometimes there is made a cavity, as L M N K, which alſo has the figure of the ſegment of a circle.

Formerly the top of the caponiere was covered with ſtrong planks, whereon much earth was laid; ſmall loop-holes were made thro' the planks or walls at the ſides to fire upon the enemy, but the ſmoke being very troubleſome to thoſe within, and their fire not ſo free as when open, occaſioned theſe ſorts of covers and ſides to be ſuppreſſed.

To deſcribe the profil of a ſection of the rampart, foſsè, covert way, and glacis of a fortification.

WE have already explained the meaning of an orto-graphical ſection or profil; to deſcribe it we muſt ſuppoſe a work to be cut from top to bottom by a plane perpendicular to the horizon; but it muſt be conceived that the meaſures are taken for the profil according to the known breadths of the ſeveral parts, and not upon the line *d e*, which cannot be drawn at right angles with all the lines of the Plan, and therefore where it is not, the meaſures taken upon it would prove falſe. Fig. 19.

To deſcribe the profil of a fortification, begin by making a ſcale of due proportion, many times greater than that of the plan; this done, draw the horizontal line A B, to expreſs the ſurface of the ground. All the parts above this line ſhew what has been raiſed, and thoſe below it what has been ſunk below the ſurface of the ground; from the point A to C, upon the line A B, ſet off four fathoms and a half, allowed for the interior talus of the rampart; at the point C raiſe the perpendicular C D of three fathoms for the height of the rampart, and draw the indefinite line D N parallel to A B; make D E five fathoms for the breadth of the terre plein of the rampart, excluſive of the banquet; at the point E raiſe the per-

pendicular

pendicular E F of two feet for the height of the banquet, and draw F H parallel to D N; make F G and G H three feet each, and join E G for the talus of the banquet, G H ſhews the breadth of the upper part of the banquet.

At the point H raiſe the perpendicular H I four feet and a half for the height of the parapet above the banquet; from the point I draw I K parallel to D N; ſet off I L one foot and a half, and join H L for the interior ſide of the parapet; make L K three fathoms for the thickneſs of the parapet, and from the point K let fall the perpendicular K P, prolonged indefinitely beneath the horizontal Line A B; give to K M two feet and a half, and draw the line L M for the ſuperior talus of the parapet; this talus admits the ſmall-ſhot to fall on the Glacis, and in the covert way even to the border of the counterſcarp; otherwiſe, let the line L K be prolonged, the ſhot fired in that direction would go far beyond the extremity of the glacis, which, if the enemy had paſſed, he would not be annoyed in the leaſt by the fire from the ramparts of the place.

The line K P will be interſected at the point N by the line D N; at this point deſcribe a ſemicircle with a radius of one foot, this will repreſent the cordon, which, when the works are lined quite to the top, is always on a level with the terre plein of the rampart.

Allow from N to P ſix fathoms, and from the point P draw the indefinite line P *n* parallel to A B, this line ſhews the bottom of the foſsè, the depth of which below the horizontal line is equal to the height of the rampart above this line, not including the parapet.

Set off from N to O five feet for the thickneſs of the lining at the cordon, and draw the indefinite line O Q parallel to the line N P, for the interior ſide of the lining.

Upon

Upon the line P *n* give to P R ſeven feet for the talus of the maſonry or brick-work, this is about the fifth part of the height N P; join N R for the eſcarp or exterior ſide of the lining; afterwards make R S one foot for that part of the foundation which jets out beyond the eſcarp, and draw S T, perpendicular to P *n*, two or three fathoms lower than the bottom of the foſsè, to which make T Q parallel to interſect O Q in the point Q.

To deſcribe the lining of the parapet, commonly called the *tablet*, draw the line Y & parallel to N M at three feet diſtance, which ſpace ſhews the thickneſs allowed to this lining.

If the profil of this ſection is deſigned to fall upon a counterfort, that is a pillar placed to ſupport the wall, give to the line O V nine feet, and draw V X parallel to O Q, and the figure O Q X V will repreſent the profil of the counterfort.

The terre plein of the rampart is made ſloping for the rain-water to run off, therefore take one foot and half from D to W, and join W E for the ſuperior part of the parapet; likewiſe A W to expreſs the interior talus of the rampart.

For the breadth of the Foſsè, ſee what is in the ichnographical plan; we have made it 20 fathoms, therefore carry that extent upon the line P *n* of the profil from P to *n*, and at the point *n* raiſe a perpendicular to meet the horizontal line at the point *m*, which is the border of the counterſcarp; at three feet from the line *m n* draw the parallel *z y*; to have the thickneſs of the lining, make *n u* three feet alſo, and join *u m* for the talus of the lining of the counterſcarp; then finiſh the foundation proportionably in the ſame manner as that of the rampart.

For

For the profil of the covert way and glacis, take four fathoms from *m* to *c*, and at the point *c* raiſe a perpendicular *c d* two feet high for the banquet, let *d f* contain one fathom, and be drawn parallel to A B, which divide into two equal parts, ſo that *e f* be three feet; join *e c* for the talus of the banquet, at the point *f* raiſe a perpendicular *f l* of four feet and a half for the height of the parapet of the covert way above the banquet; bring down *l f* to interſect A B at the point *r*, and for the breadth of the glacis make the interval from *r* to *g* 20 fathoms; then join *l g* to repreſent the ſloping of the glacis; make the diſtance from *l* to *h* of one foot, and draw the right line *h f* to have the interior ſide of the parapet of the covert way. Thus the whole profil is finiſhed after you have marked out the paliſade upon the banquet, as is ſeen in the figure, it is ſix or ſeven feet long, and has its head ſtuck with ſome few iron points to catch the aſſailants by their cloaths or accoutrements.

We have juſt now ſaid, that a counterfort is a pillar
Fig. 20. placed within the earth of the rampart to ſupport the wall, their diſtances one from another is never more than betwixt fifteen and twenty feet, and they are always raiſed as high as the cordon of the lining, or two feet higher, to
Fig. 21. ſtrengthen the parapet. The figure deſigned to ſhew the ſtructure of their plan, will ſerve for us to explain the different parts; A B is the interior ſide of the lining; the line C D is called the *root* of the counterfort, and E F is denominated the *tail*; I H is the *length* of the counterfort.

M. *de Vauban* has calculated a particular table for the ſolidity of counterforts in the following manner; he affirms to have known it ſucceſsfully put in practice at 150 fortified places.

The

Plans of Ancient Walls with the different disposition of t

Towers

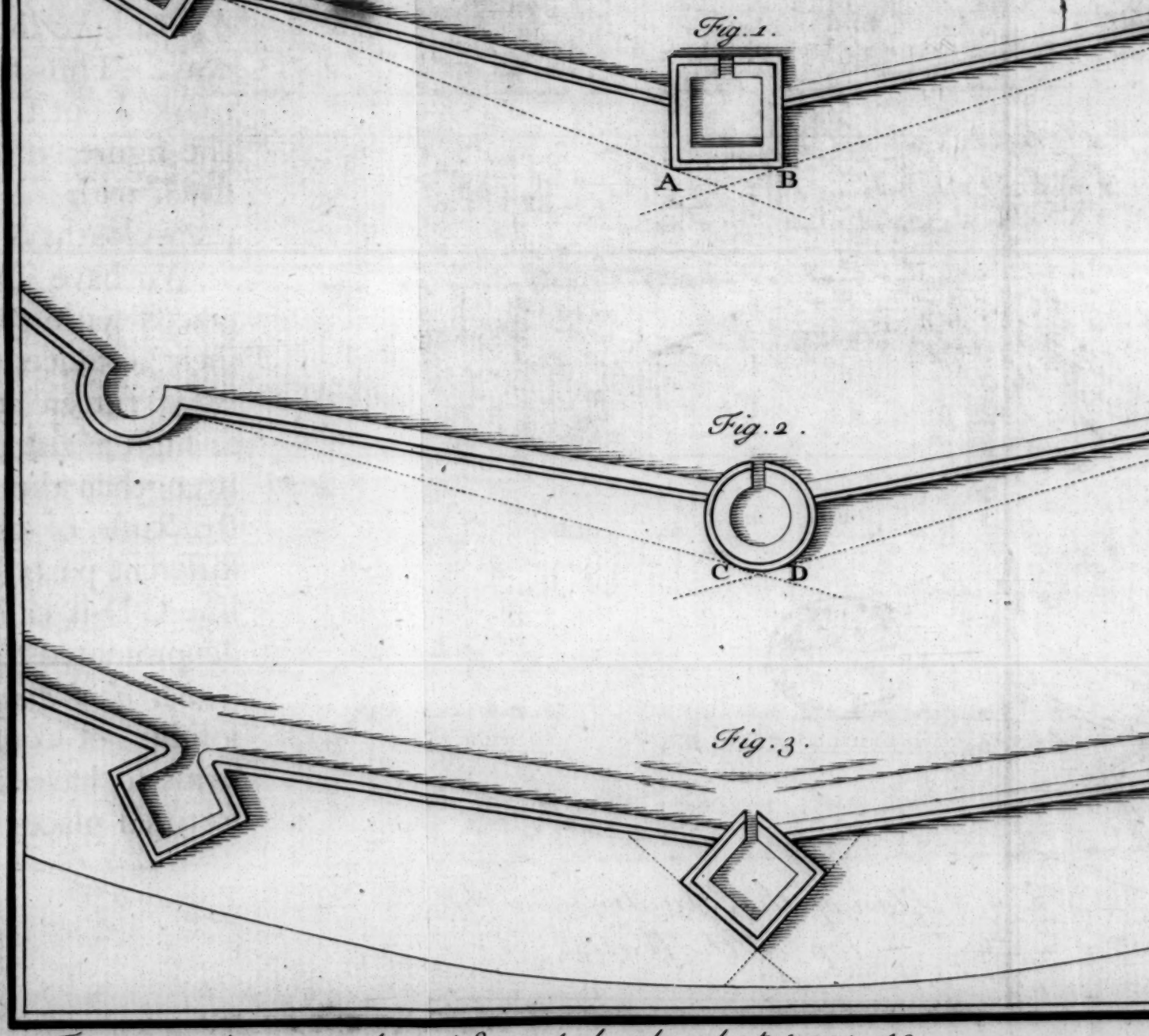


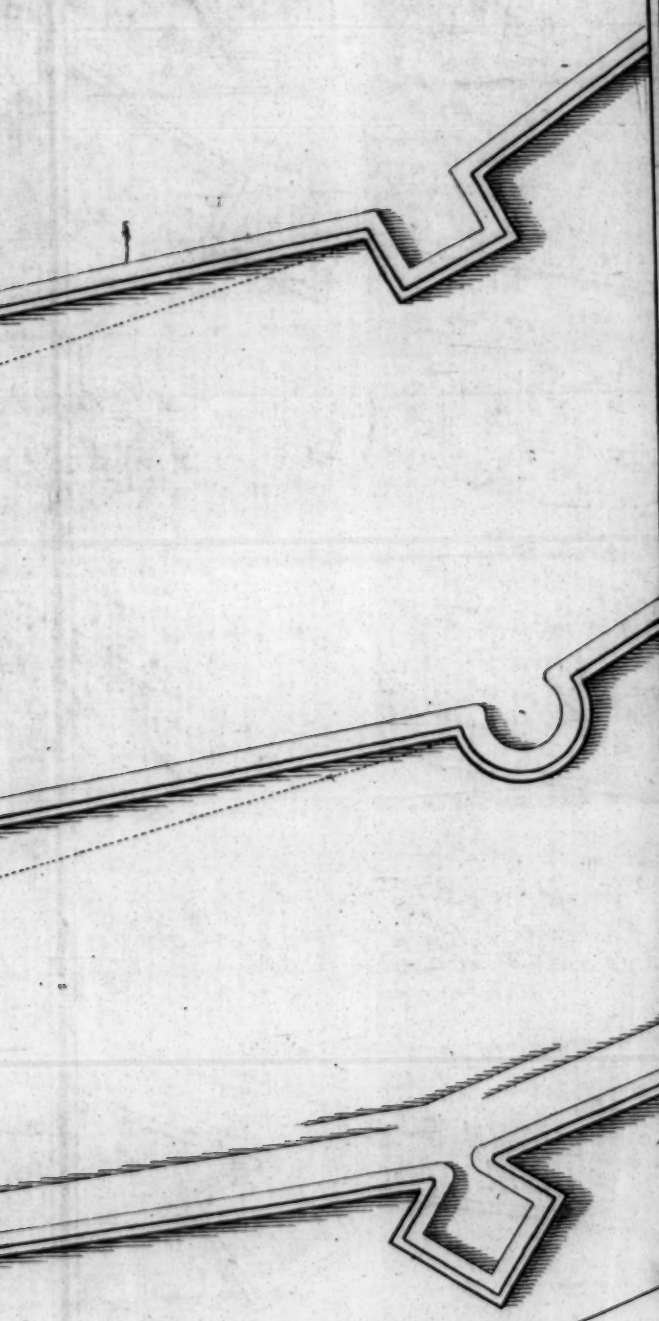
Fig. 1.

Fig. 2.

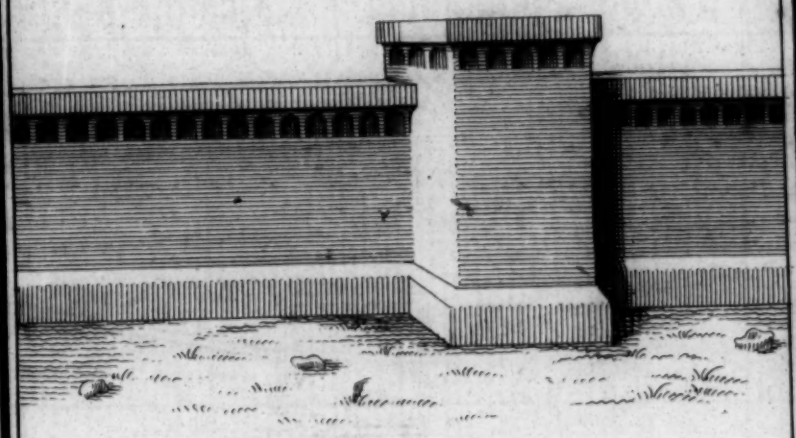
Fig. 3.

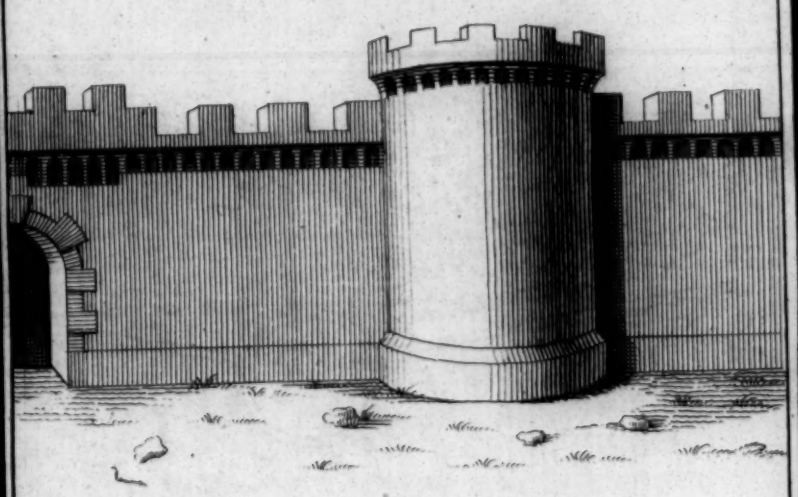
The eight plates, numbers 1 to 8. are to be placed at page 40.

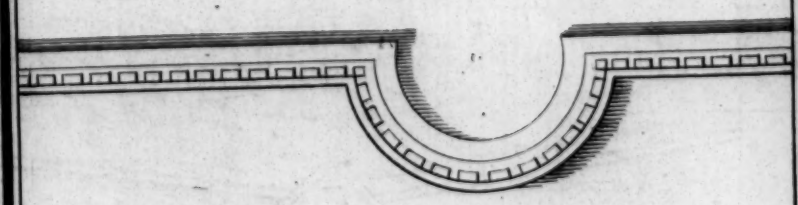
position of round & Square



View of the Ancient round & Square Towers







Plan of the Murdresses at the top of the Walls.

The Square & Pentagon Fortifie

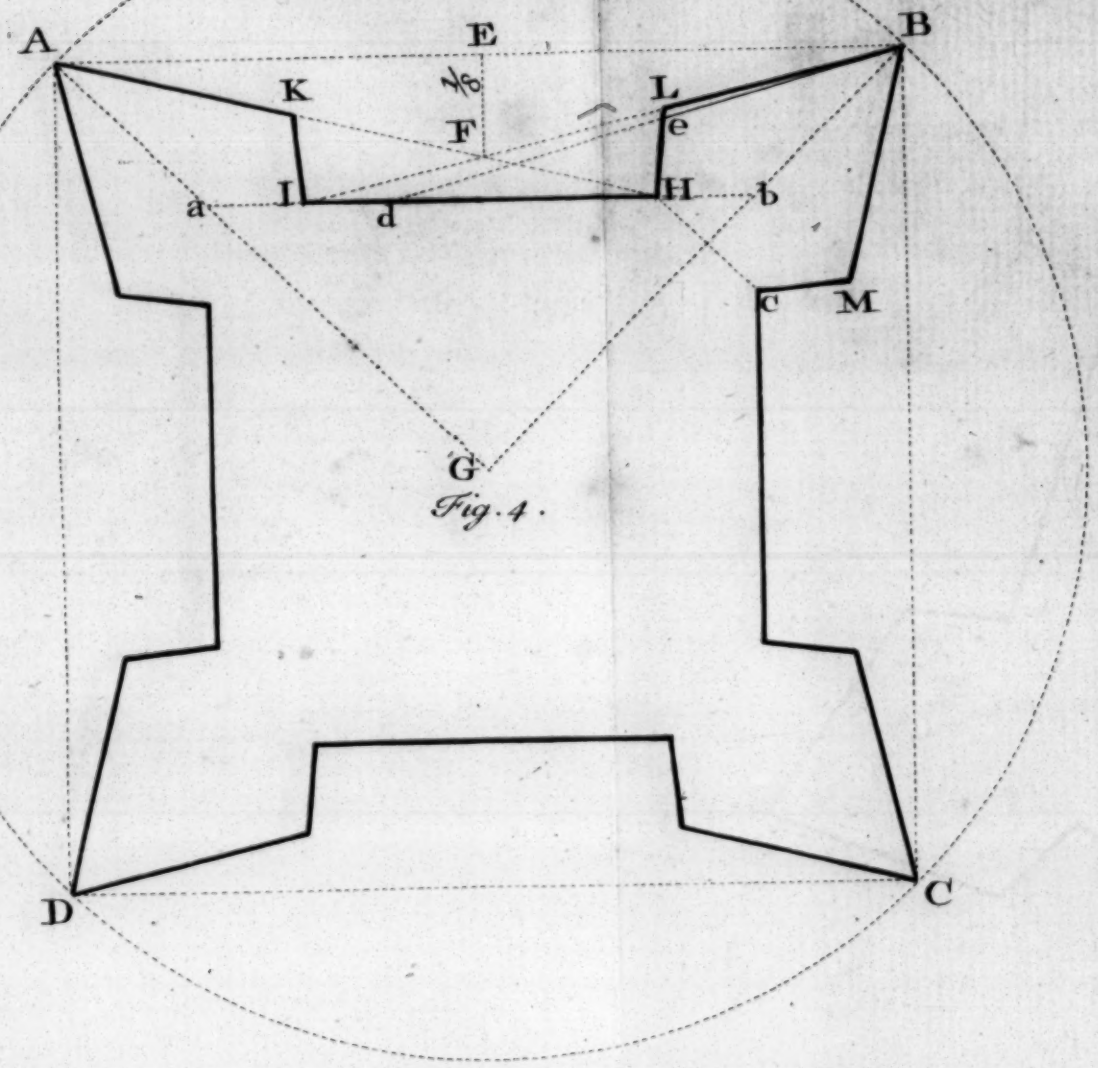


Fig. 4.

on Fortified according to M. Vauban.

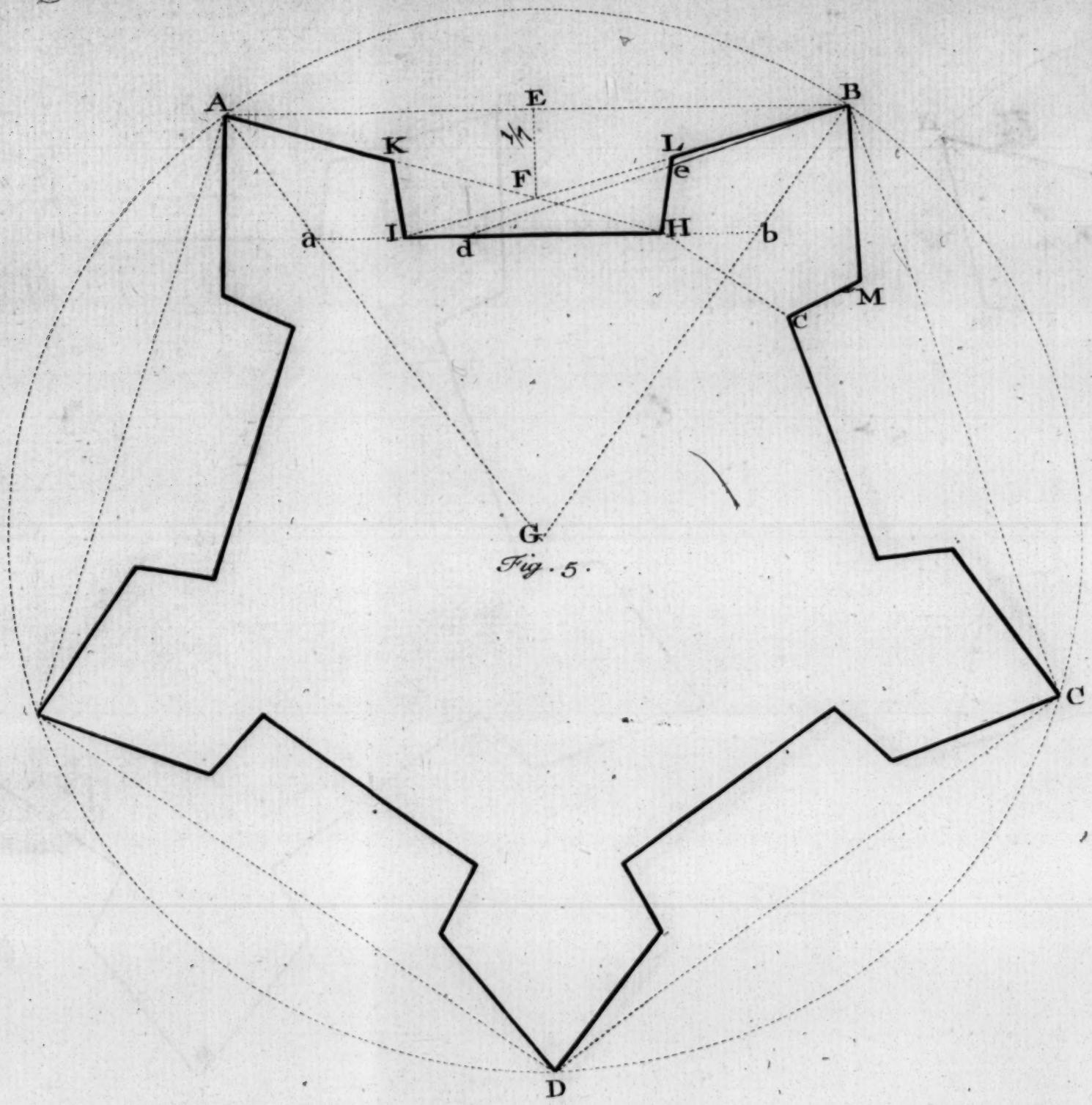


Fig. 5.

Hexagon Fortified accordin

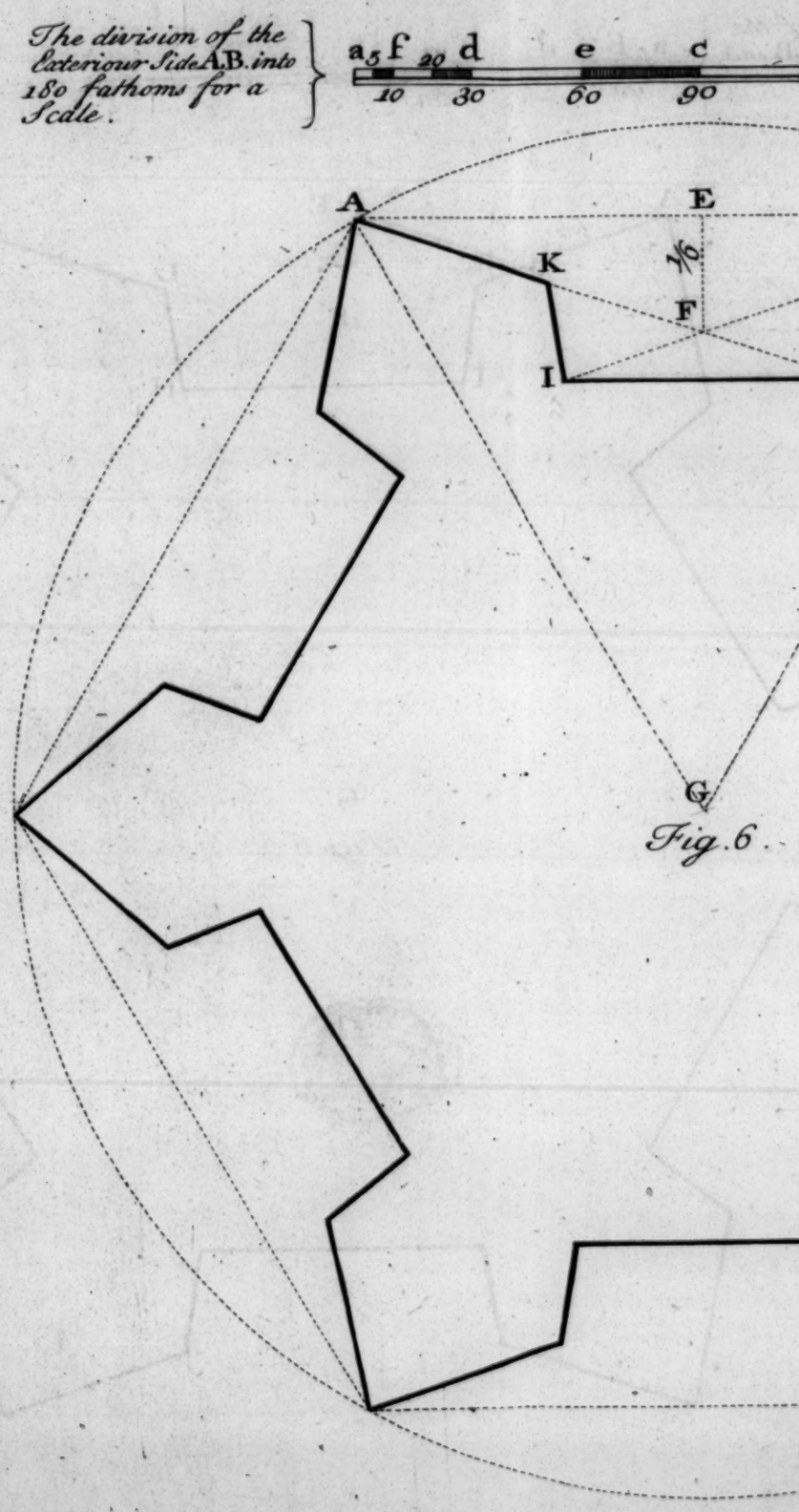


Fig. 6.

ed according to M. Vauban

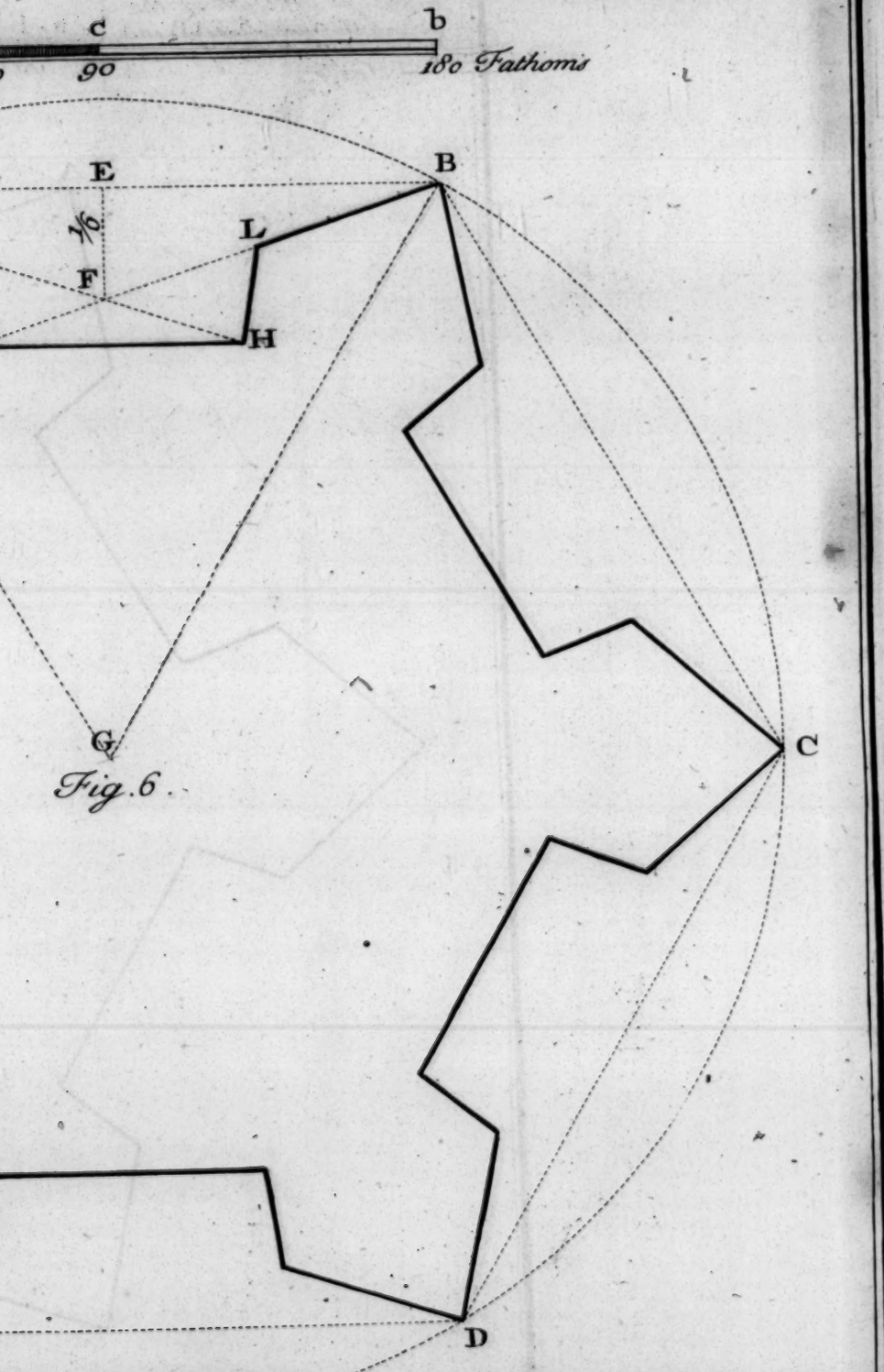


Fig. 6.

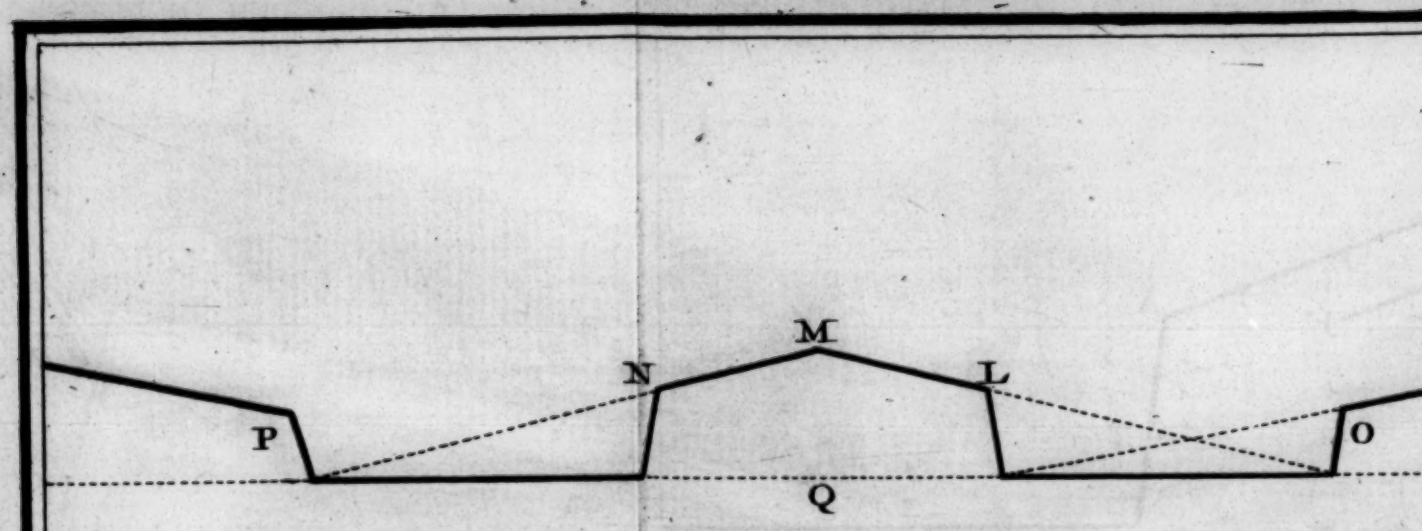


Fig. 9.

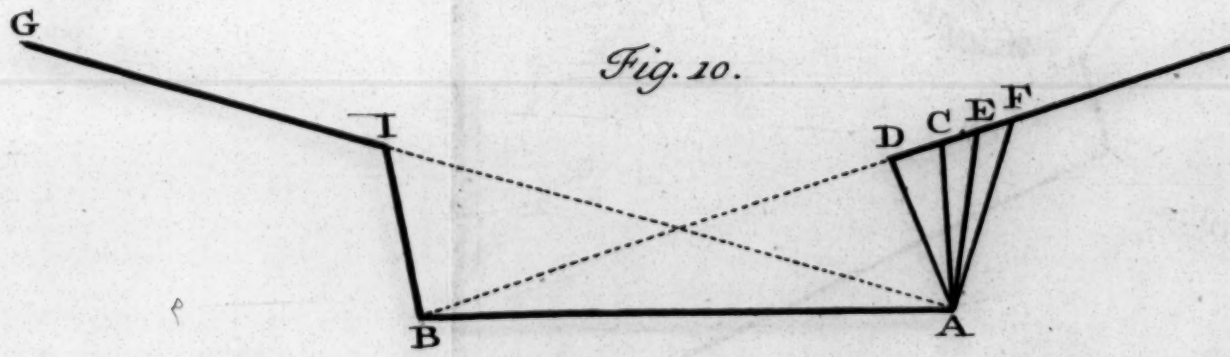


Fig. 10.

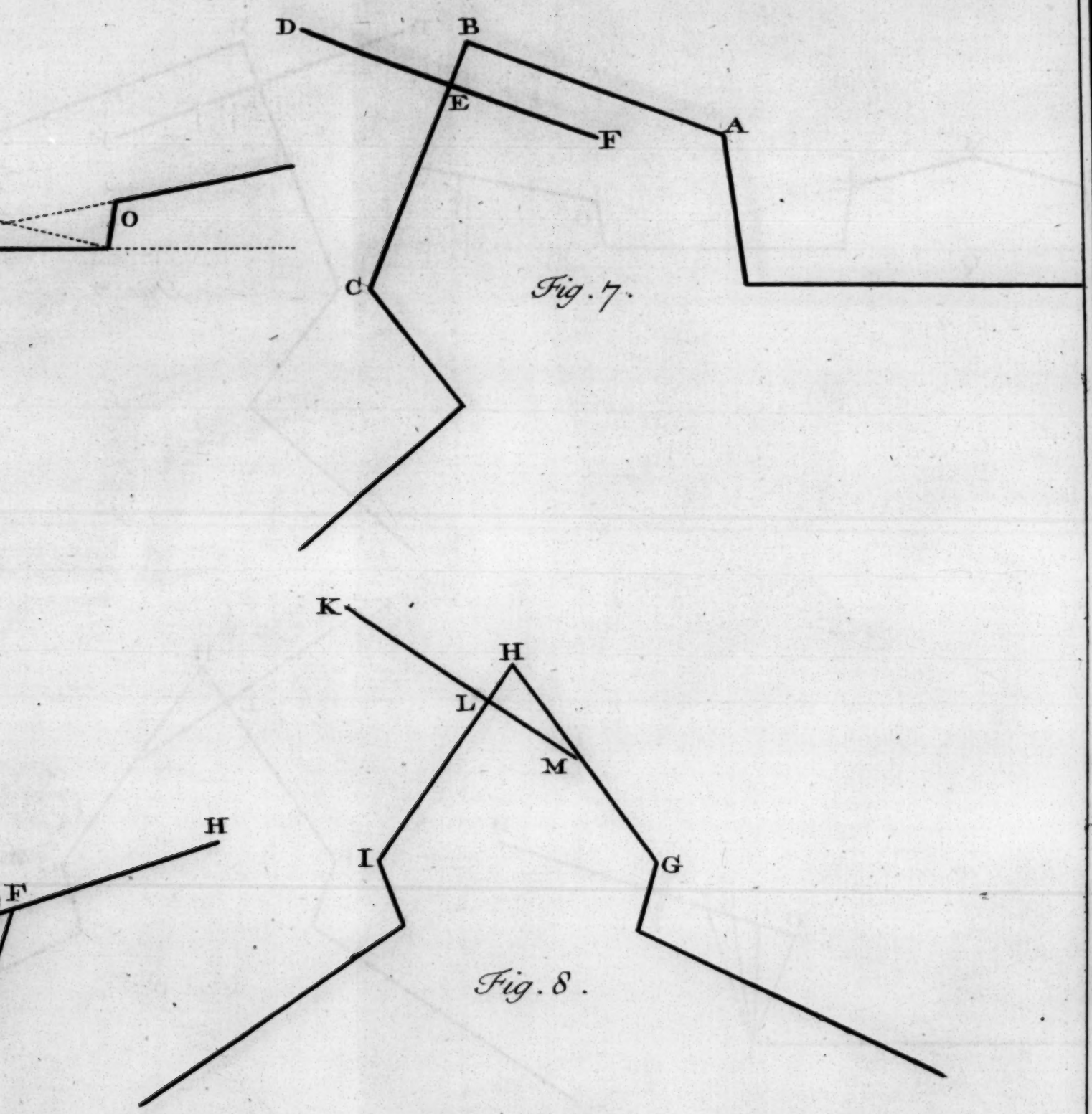


Fig. 7.

Fig. 8.

Plan of the Rampart, Parapet, Fossé, Covert way, a

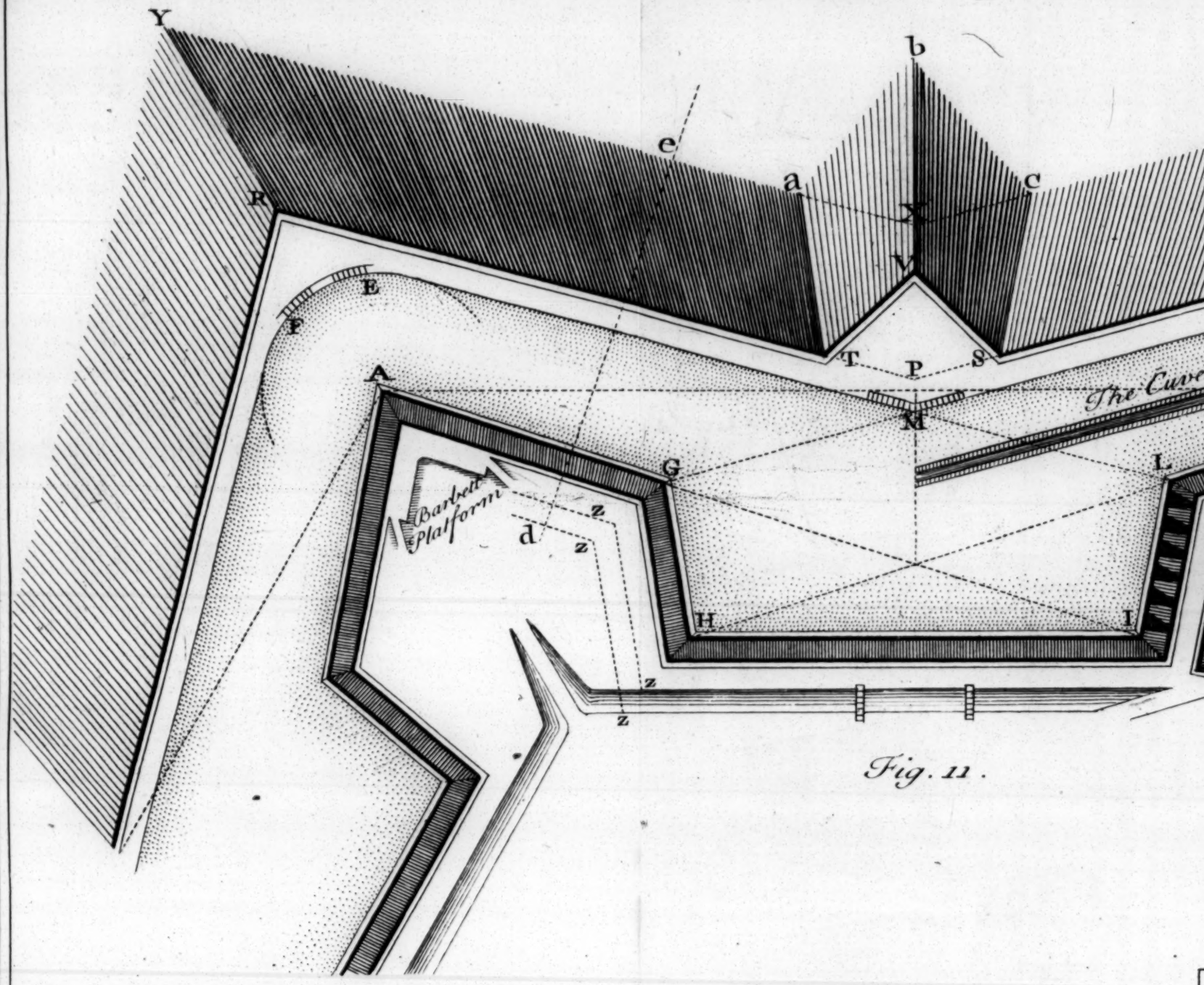
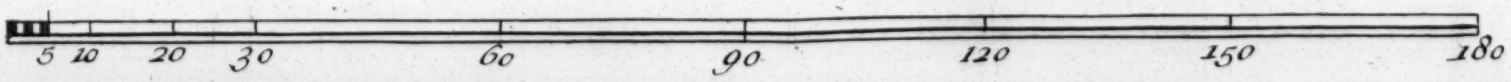


Fig. 11.

A Scale of 180 Fathoms.



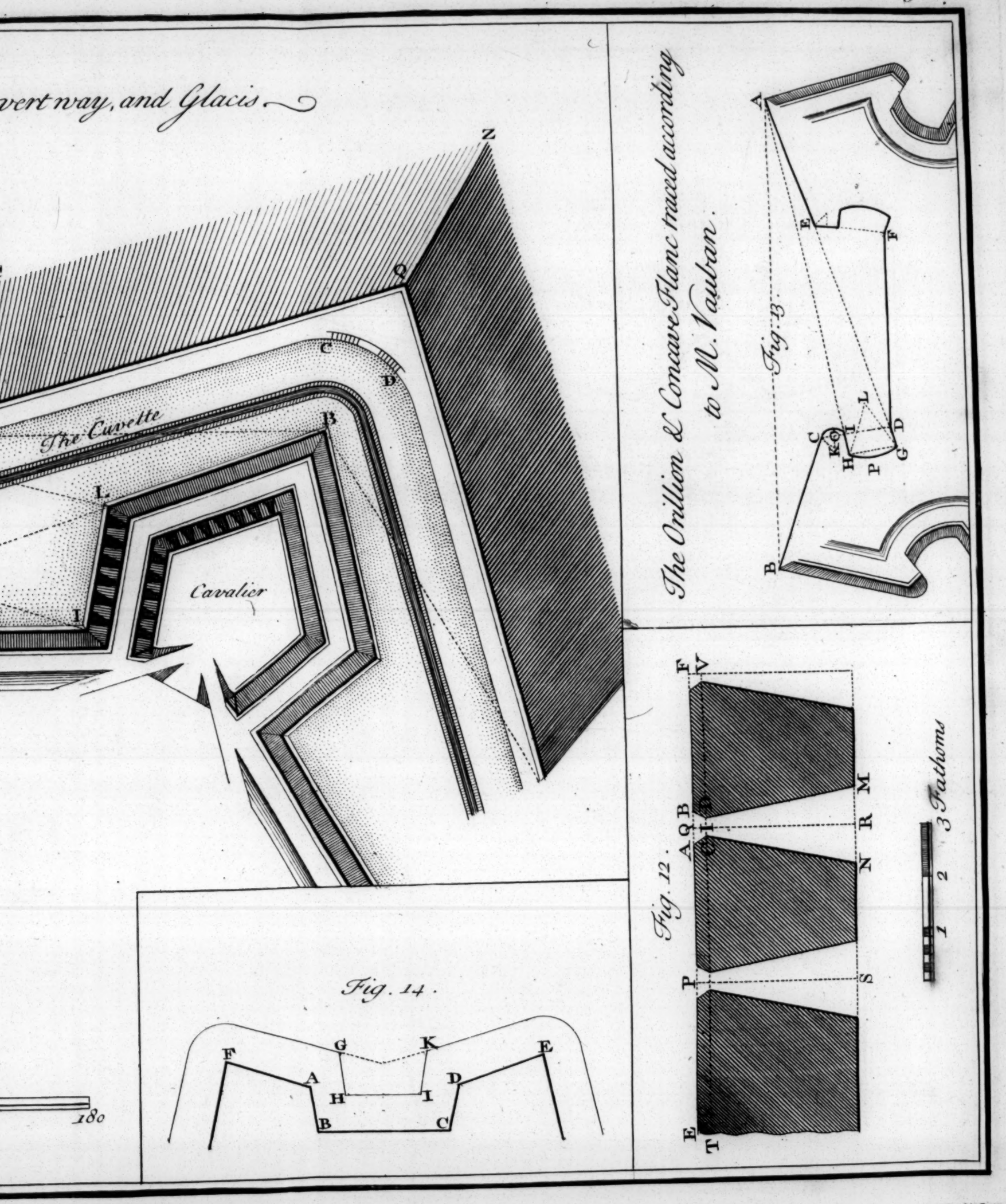

vert way, and Glacis
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Fig. 14.
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The Orillion & Concave Flanc traced according to M. Vauban.
Fig. 13.
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Fig. 12.
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1
2
3 Fathoms

A Scale of 90 Fathoms for the four Figures of this Plate

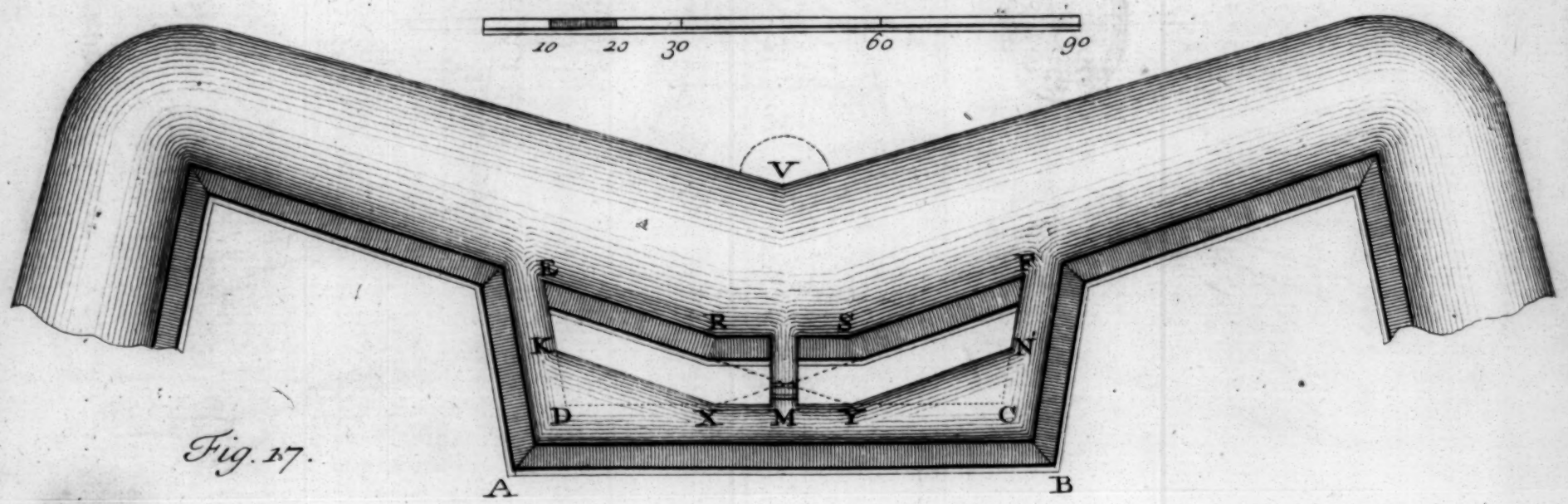


Fig. 17.

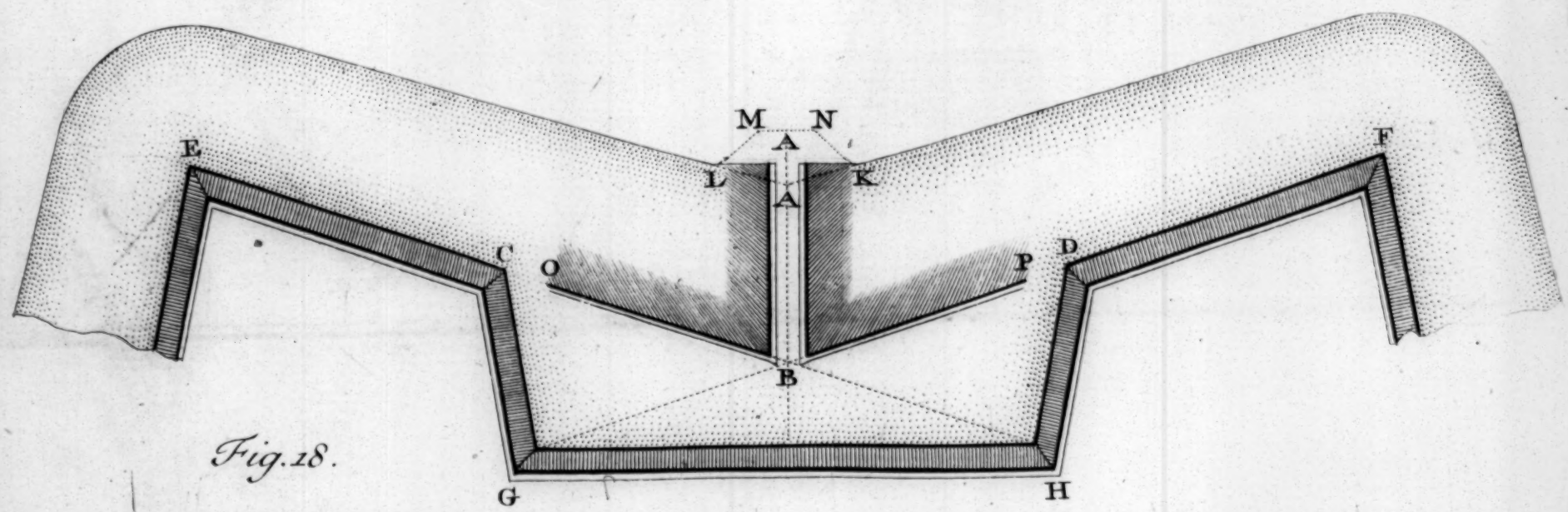


Fig. 18.

Pla. 6.

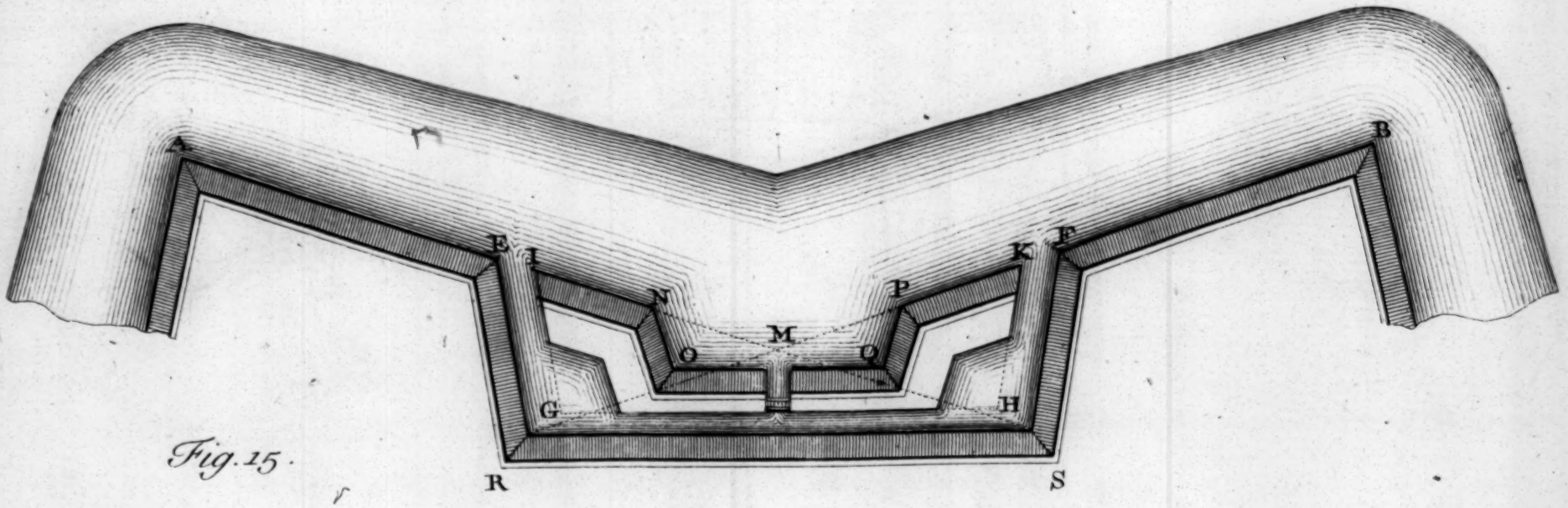


Fig. 15.

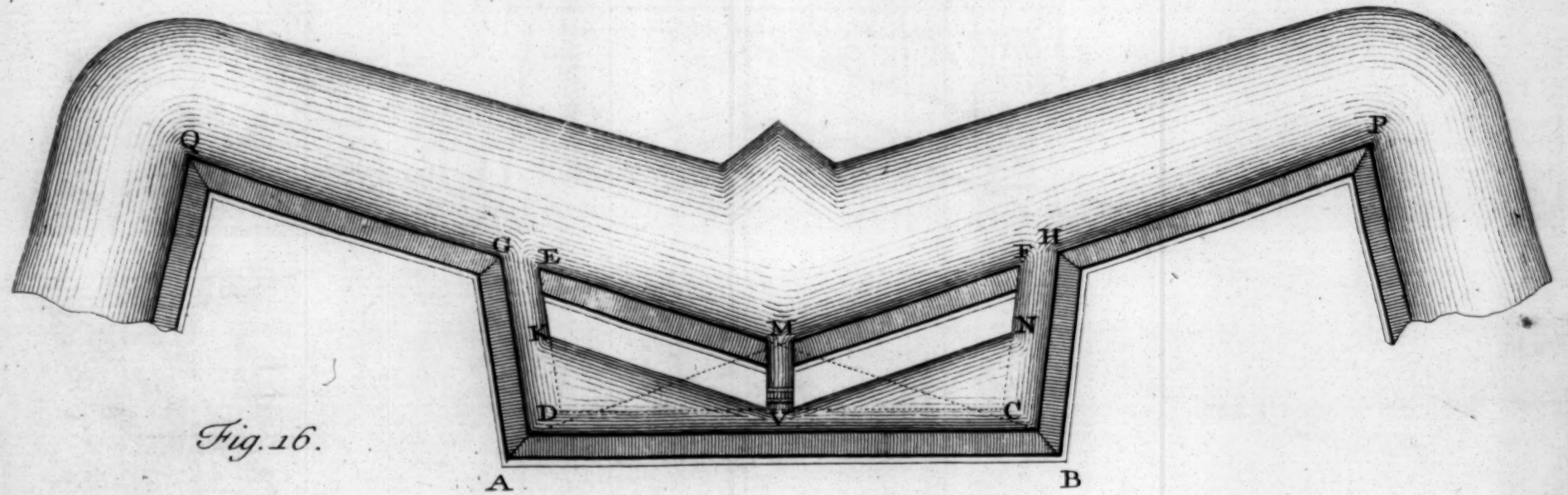


Fig. 16.

A Scale of 90 Fathoms for the four Figures of this Plate

Profil of the section of the Rampart, Fossé, Co

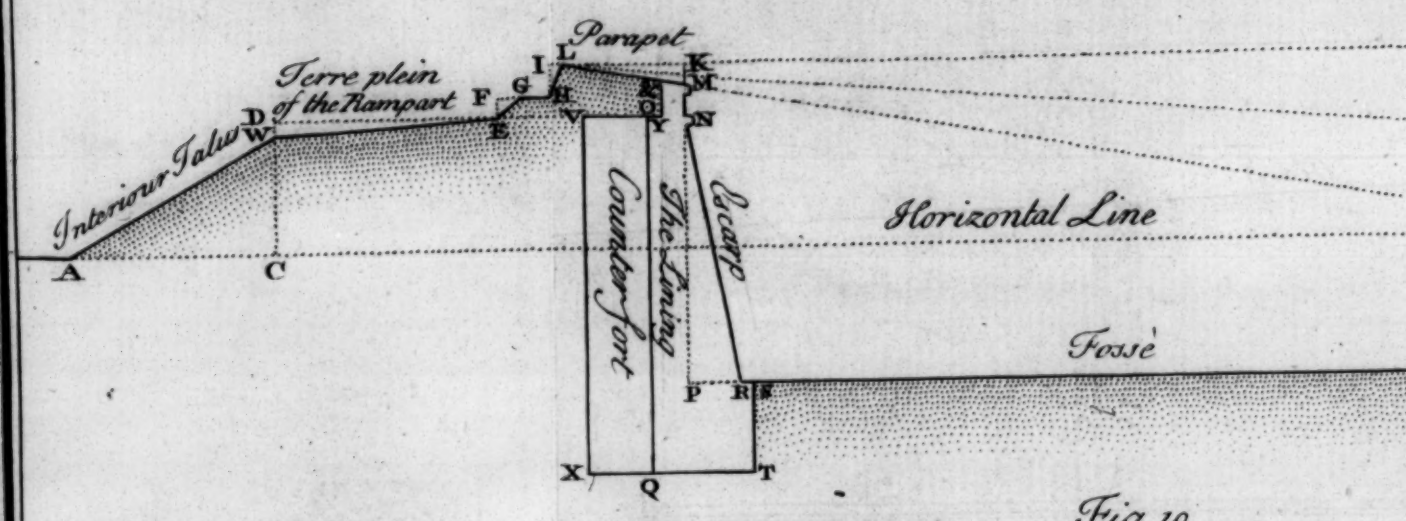


Fig. 19.

Viens of eight different figures given to Counterforts.

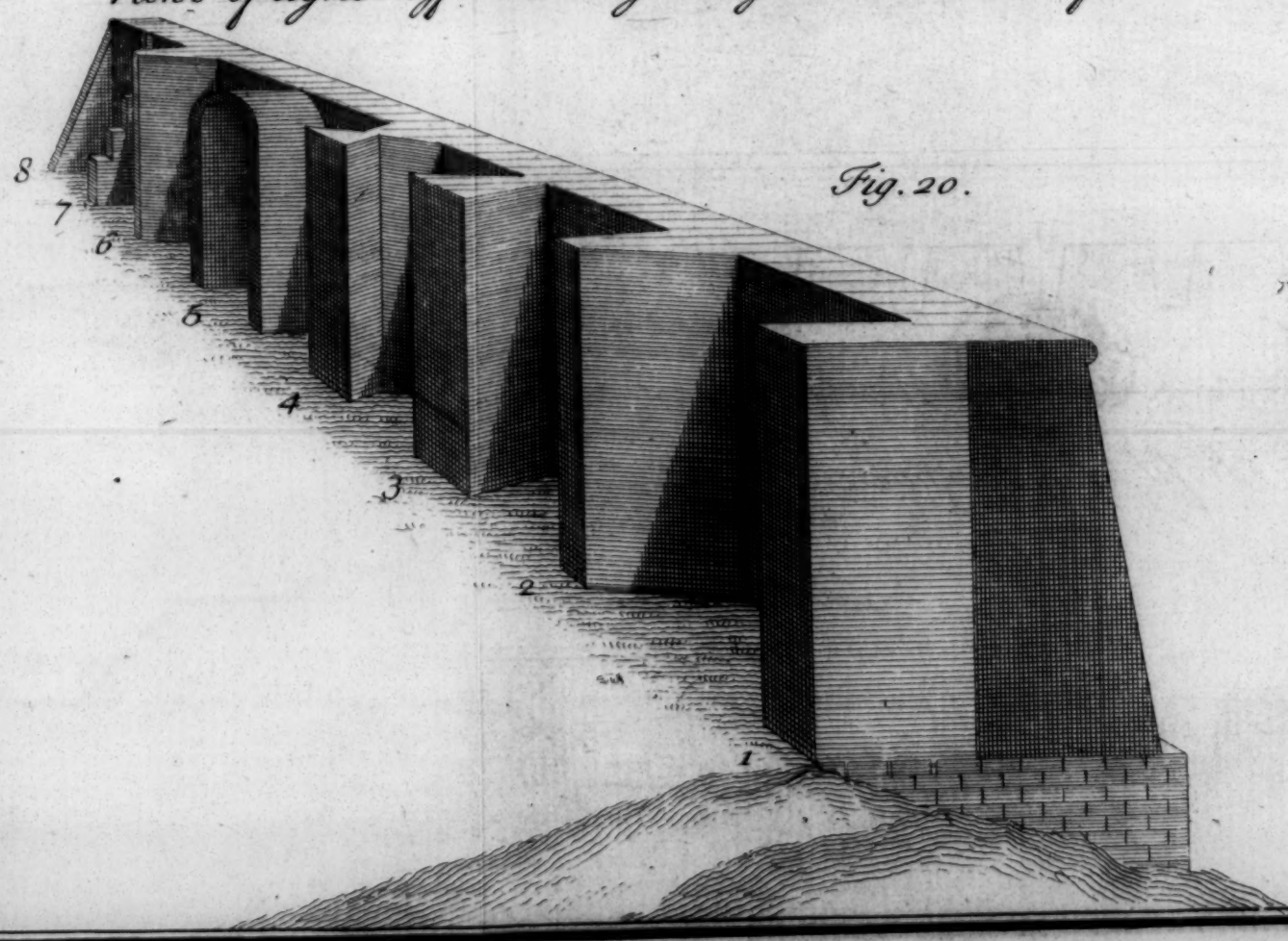
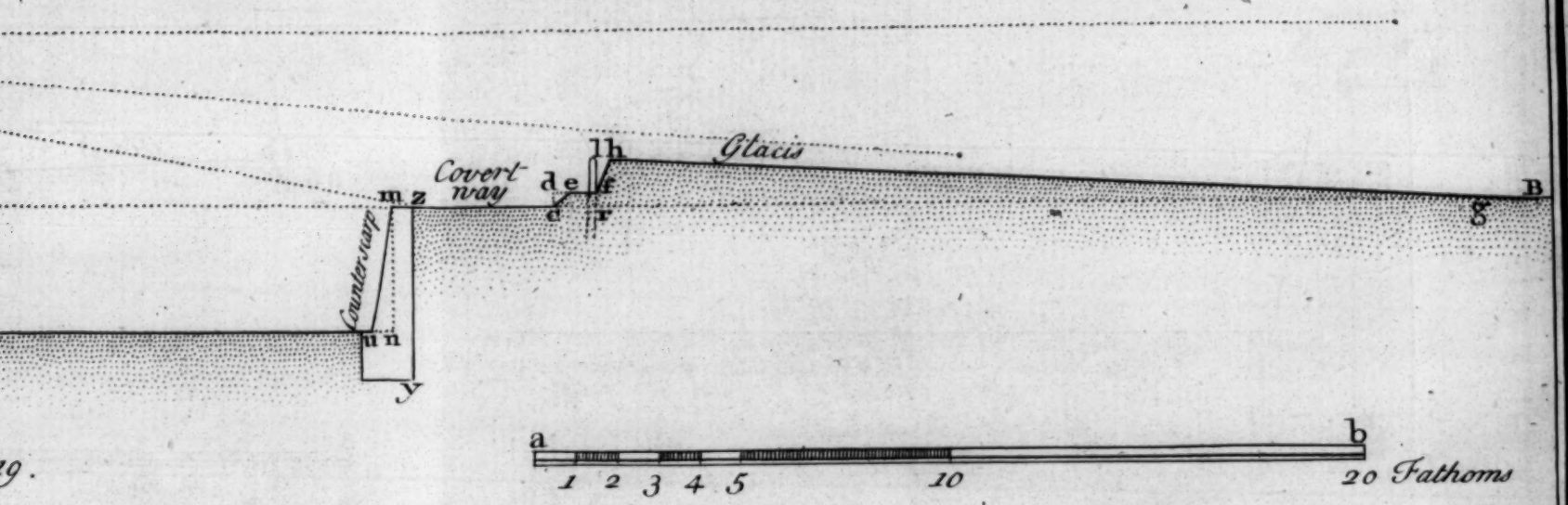


Fig. 20.

art, Fosse, Covert way, and Glacis taken upon the Line d, e Fig. 11.

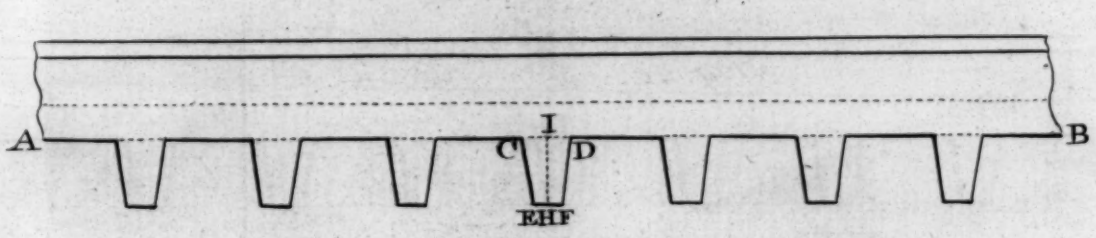


19.

terforts.

Plan of the Counterforts For the above Profil upon the same Scale.

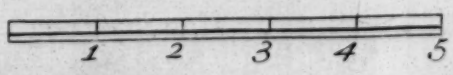
Fig. 21.

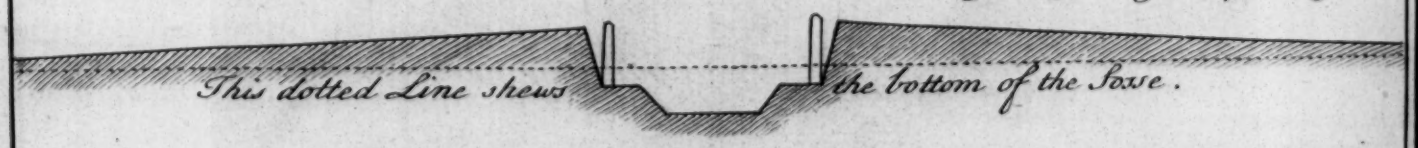


Profil of a Caponiere.

Fig. 22.

a Scale of 5 Fathoms.





Four different Profils of t

Fig. 23.

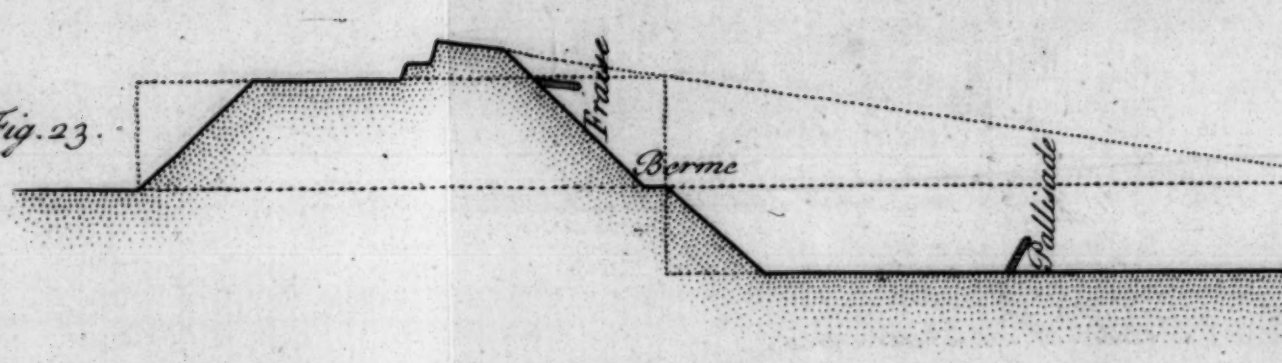


Fig. 24

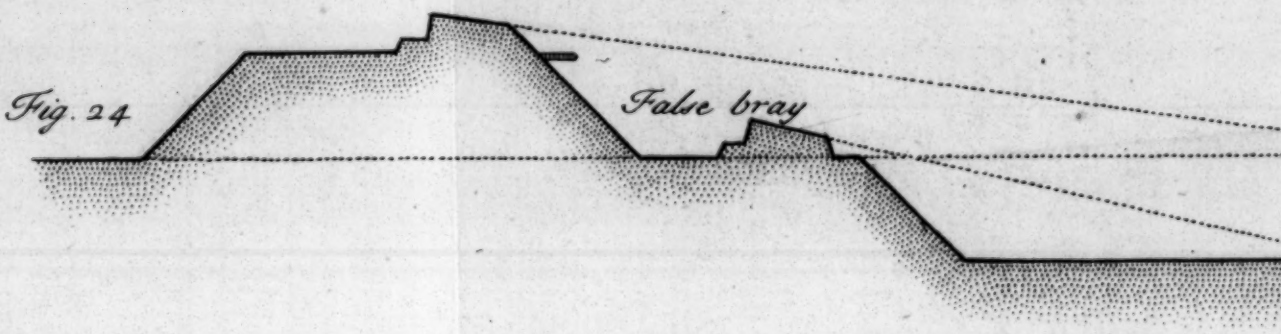


Fig. 25

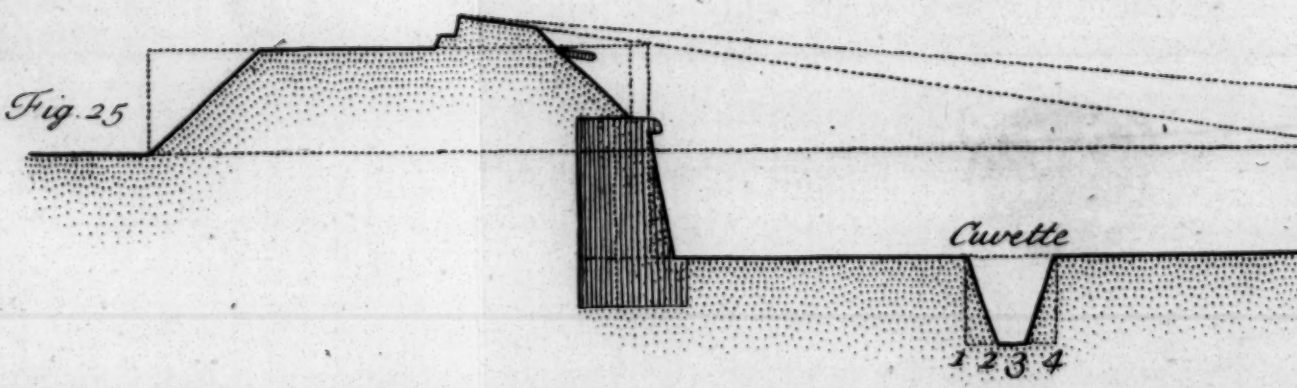
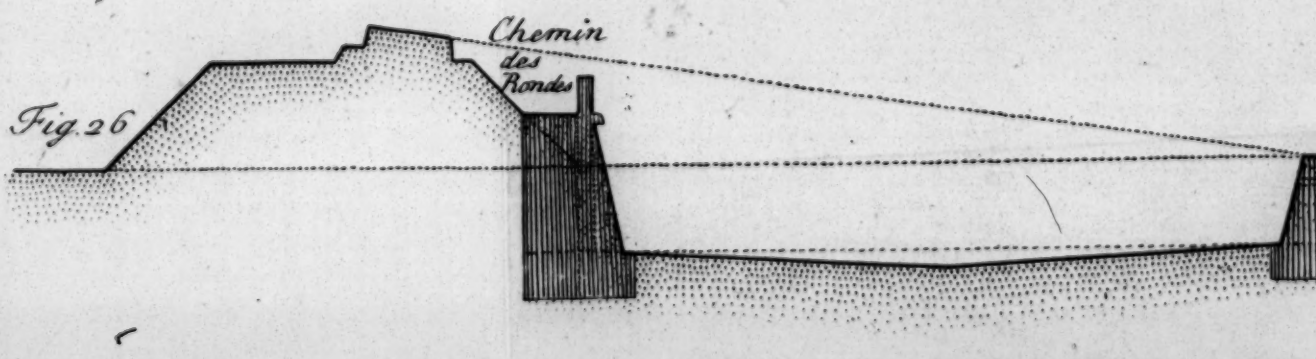
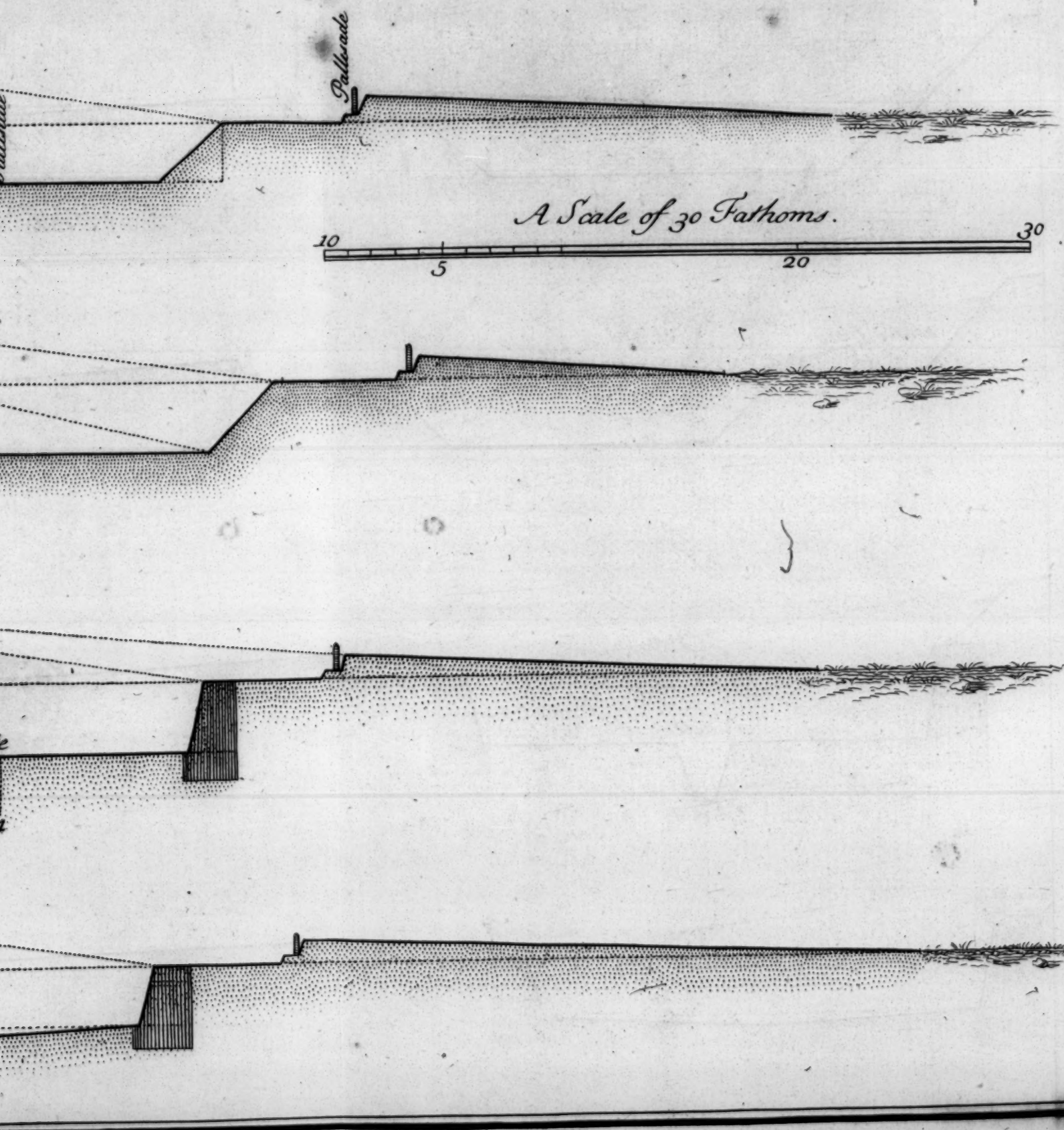


Fig. 26



ofils of the Sections of Ramparts.



The thickneſs of a counterfort ten feet high, at the root is three feet, and increaſes in proportion one foot for every ten feet of elevation; ſo that let the height be 36 feet, the thickneſs at the root becomes five feet ſix inches.

The length of a counterfort intended to ſupport a lining ten foot high is four feet, and for every ten feet more in height it is allowed two feet; thus for a counterfort 36 feet high, the length is nine feet.

The thickneſs of a counterfort at the tail, of ten feet elevation, is two feet, and as it is raiſed higher give to every ten feet, eight inches; therefore ſuppoſe the height 36 feet, the thickneſs at the tail is three feet eight inches.

There are works lined three quarters two thirds, or only half the height of the ramparts; their profil is deſcribed by knowing their meaſures, and proceeding in the method juſt now given.

The thickneſs of a half or three-quarter lining for a rampart, is the ſame as if the lining was continued to the top; for example, if there was fifteen feet of turf raiſed above the lining twenty feet high, the thickneſs of the lining at the top muſt be increaſed three feet, which added to the five feet already given, makes it eight feet thick.

The ſize and ſolidity of counterforts is augmented in proportion to the elevation of the rampart; for example, ſuppoſe the height of the work from the bottom of the foſſe 35 feet to the top of the rampart, 20 of which were lined, and the other 15 feet of turf; the counterforts muſt be allowed the ſame dimenſions as if they were deſigned for a lining 35 feet high, for the ſame thickneſs is allowed

to a lining 20 feet high, intended to ſupport the preſſure of earth raiſed upon it 15 feet in height. Theſe remarks are from M. *de Vauban*, but we will cloſe a ſubject not deſigned to be treated of in theſe ſheets.

The repreſentation of the profil of a caponiere is not
Fig. 22. omitted, whoſe plan is deſcribed in the foregoing ſection.

When the rampart is made without any lining, there is a little ſpace, called the *berme*, of four or five feet, left at the foot of it without, to prevent the earth falling into the foſsè.

Beſides the paliſades upon the banquet of the covert way, there are others named *fraiſes*, of ſeven or eight feet long, driven almoſt half way into the earth of the rampart on its exterior ſide, when not entirely lined, and a little below the parapet; they are not ſet parallel to the horizontal line, but preſent their points ſloping towards the field, and are of uſe to prevent deſerters from the ga-
Fig. 23, riſon, and ſurpriſes from an enemy. There are four diffe-
24, 25, rent profils of ramparts added, which will ſerve to give a
26, 27. general notion how the profils of the ſections of any works are deſcribed, the different meaſures of the heights and breadths being given.

We have choſen to lay down in this, and the next chapter which treats of the outworks, *&c.* the conſtruction of M. *de Vauban*, becauſe it is the moſt eaſy; yet there could have been introduced a ſyſtem different from all others, and conformable to the maxims already eſtabliſhed: Therefore it is proper to obſerve, that the meaſures hitherto or hereafter mentioned are not ſo abſolutely determined, but that a perſon of skill and prudence may either increaſe or diminiſh them as he ſees occaſion for ſuch variations; however it muſt be in ſuch

a

a manner as not to prove contrary to the moſt eſſential maxims of the art; let the following inſtance explain our meaning.

In all polygons above the eptagon, it would be better to give only the fifth part of the exterior polygon to the perpendicular; this would make the baſtions more ſpacious, and the flanked angles leſs obtuſe.

CHAPTER II.

OF THE OUTWORKS.

OUTWORKS is the general name for ſuch pieces of fortification as are raiſed beyond the foſsè of the place. They were invented to increaſe the ſtrength of a place, and ſerve to cover the bridges, gates, and other weak parts; to join to the fortifications of the town any eminences that command it, if they are not at too great a diſtance; to incloſe the ſuburbs; in ſhort, to lengthen out the time of the defence, becauſe the beſiegers muſt make themſelves maſters of the outworks before they can advance to the body of the place. The moſt common and uſeful of theſe ſorts are *half-moons*, *counter-guards*, *horn* and *crown-works*, *great* and *ſmall Lunetts*, &c.

The diſpoſition of the figure for any of theſe works, is eſtabliſhed upon the ſame principles which have been laid down for the ſtructure of the fortifications that ſurrounds the body of the place. There muſt be no part in any one of them but what is ſeen and flanked either by the body of the place, or by ſome other part of itſelf, or by ſome adjacent outwork; ſo that the enemy cannot place himſelf any where without being diſcovered. And as it has been judged neceſſary that the fortification of the body of the place ſhould be made capable of being defended by muſquetry, as well as by great guns, for this reaſon no parts of the outworks muſt be rendered incapable of receiving likewiſe their defence from musketry; therefore thoſe which are flanked by the body of the place muſt not be above musket-defence from the parts that flank them; moreover, the other parts of outworks which mutually

tually defend each other, muſt be within the extent allowed for the defence of the muſquet that has already been fixed from 120 to 140 fathoms; they have ramparts and parapets, as there are to the fortification of the body of the place, but what is particularly to be conſidered in the ſtructure of outworks is,

I. Their conſtruction to be ſuch, that after the beſiegers have drove the beſieged from any one of them, and have taken it, they find it impoſſible to cover themſelves in it from the fire of the place, or of the other outworks.

II. The ramparts of outworks muſt be lower than that of the place, which ought to command them. When there are ſeveral outworks, one before the other, that which is neareſt to the place muſt have its rampart three feet lower than that of the place, and the outwork which is raiſed juſt before this muſt have a rampart three feet lower yet, and ſo on; for example, if there were three outworks juſt before one another, and the rampart of the place ſuppoſed to be raiſed eighteen feet, the rampart of the firſt outwork neareſt to the place would only be fifteen feet; that of the ſecond, twelve feet; and that of the third or exterior one, nine feet; thus the outworks neareſt to the place command thoſe which are more remote, and the rampart of the place commands them all in general.

III. Every outwork muſt be ſurrounded by a foſsè which communicates with the foſsès of the body of the place, and is made as deep if they are to be filled with water, otherwiſe it is leſs deep, that the foot of the ramparts of the outworks may be more eaſily defended by ſuch parts in the fortification which flank them. The breadth of the foſsès of all the chief outworks is ten or twelve fathoms, and their ſaillant angles are made circular, as it has been done for the foſsè of the place.

IV. The

IV. The parapet for the outworks is as thick as for the body of the place, becauſe every where it muſt be proof againſt the battering of cannon. The terre plein of the rampart for outworks is three or four fathoms broad, and its talus in proportion to its height.

Obſerve, when you deſign to draw any outworks to a plan, not to admit any line beyond the *line of counterſcarp* that fixes the breadth of the foſsès, but what ſerves for the ſtructure of the work that is to be deſcribed.

To deſcribe a half-moon.

THE *half-moon* L M N, formerly called a *ravelin*, is a work almoſt of a triangular figure that is raiſed before the curtins, and conſiſts of two faces L M, M N, making a ſaillant angle L M N, with two demigorges R L, R N, taken upon the counterſcarp of the place.

For the ſtructure of a half-moon before a curtin 3 F, you muſt make two points O P upon the faces 1 E, H 2 of the baſtions, at four fathoms diſtance from the angles of the ſhoulder E and H; then from the point F, taken as center, deſcribe an arch, which is to be interſected at the point M by prolonging outwards the perpendicular B R, this interſection gives the ſaillant angle of the half-moon. Draw the lines M O, M P, which interſect the counterſcarp at L and N, and the faces are determined by the M L, and M N; the demigorges of the half-moon are expreſſed by the lines L R and R N; the line R M, extending from the re-entering angle of the counterſcarp to the ſaillant angle M, is called the *capital* of the half-moon.

Fig. 1.

The parapet and rampart of the half-moon, with the talus, are drawn parallel to its faces and their breadths, according to the meaſures we have ſaid were allowed in general

general to outworks; thoſe parts in them, as the gorges, which look towards the place, are left without any rampart, becauſe it could only ſerve to cover the beſiegers, when lodged therein, againſt the fire of the place.

The foſsè of the half-moon is twelve fathoms, whoſe counterſcarp is drawn parallel to its faces till it joins the counterſcarp of the place; before the ſaillant angle M it muſt be made circular, as it was practiſed before the flanked angle of the baſtions.

The following obſervations are not to be paſſed by.

1. The principal uſe of the half-moon is to cover the curtin, the flancs and the gates. Moreover, the faces of the baſtions being only defended by one flanc, the enemy, in their approaches to that part of the covert way before the faces, is fired upon but very obliquely from the face of the oppoſite baſtion. The half-moon affords a very direct fire, beſides the ſtrength it adds in general to the body of the place.

2. The parts *r* O, P *n*, of the faces of the baſtions, taken in by the faces of the half-moon and its counterſcarp being prolonged, ſerve as flancs; for they not only flank the faces of the half-moon in their whole extent, but alſo its foſsè. The reaſon for not making the faces of the half-moon to fall upon the angles of the ſhoulder E and H, but allowing four fathoms from E to O and from H to P, is, that the thickneſs of the parapet at the ſhoulder would prevent the faces of the half-moon being defended by a fire equal to the breadth of its foſsè.

3. To increaſe the defence of the foſsè and faces of the half-moon; whenever the foſsè is dry, at the bottom of it is made a ſort of place of arms, as at *m*, with only one parapet drawn perpendicular to the faces of the half-moon, and takes up the whole breadth of the foſsè, excepting a ſmall

ſpace

ſpace next to the counterſcarp. This parapet is raiſed three feet above the bottom of the foſsè, and is ſunk three feet. It has a glacis and banquet like thoſe of a caponiere, and is paliſaded in the ſame manner. Theſe places of arms are made in all dry foſsès of the outworks.

4. Sometimes flancs are given to half-moons, and then they reſemble baſtions detached from the circumference of the place.

Fig. 1. To deſcribe the flancs of a half-moon *a b c d*, make *b g*, *d h*, taken upon the faces, each ten fathoms; afterwards *b e*, and *d f*, are allowed each ſeven fathoms, taken upon the counterſcarp; join *g e* and *h f* by right lines, and the flancs of the half-moon are deſcribed; they are to have a rampart and parapet the ſame as the faces.

5. Sometimes a ſmall half-moon, called a *reduit*, is required within the great one. The capital *a l* of this reduit is fifteen or twenty fathoms, its faces are parallel to thoſe of the great half-moon. The parapet of a reduit is a brick or ſtone wall a foot and a half thick, with ſeveral loop-holes or chinks made in it for the muſquetry to fire through; its foſsè is from four to ſix fathoms broad, and is parallel to its faces.

The reduit ſerves as a retreat for the ſoldiers who are poſted in the half-moon whenever the beſiegers are likely to become maſters of this laſt work, and the fire from the reduit greatly annoys and perplexes the enemy in their attempts to lodge themſelves therein.

6. Half-moons are raiſed before all and every curtin of the place.

To deſcribe a half-moon with lunetts.

TO augment the ſtrength of the place, the half-moon is often covered by two works, one upon each face, which taken together are called *lunetts*. There are of the great and leſſer ſort. The great lunetts cover entirely the faces of the half-moon, and the leſſer only part of them.

1. To deſcribe the great lunetts: Having finiſhed the ſtructure of the half-moon, and of its foſsè, prolong the faces B D, C D, indefinitely beyond its counterſcarp, and from the border E of the counterſcarp make E F 30 fathoms, and the point H, give to H G 15 fathoms; then join G F, and you will have half of the lunett, whoſe faces are repreſented by G F and F E, and the demigorges by H E and H G. Perform the ſame operation upon the other face C D of the half-moon, when prolonged, and the lunett will be intirely compleated. Fig. 3.

For the rampart, parapet, and foſsè of the lunett, which are traced parallel to its faces, their height, breadth, &c. may be taken from the obſervations laid down for theſe parts of the ſtructure of outworks in general. In the middle of the great lunett, for the moſt part, is made a retrenchment I H, which is nothing elſe but a rampart and parapet deſcribed parallel to the ſhort face E F, together with a foſsè three or four fathoms broad. The ſuperior talus of the parapet of the lunett muſt be in ſuch a direction, that being prolonged, it either falls upon the banquet, or towards the middle of the oppoſite covert way.

The foſsès of the lunett is defended by the ſame faces of the baſtion which flank the half-moon; the foſsè of the retrenchment is flanked by the face of the half-moon. The

flanked angle F of the lunett muſt always have at leaſt 60 degrees.

The re-entering angle K of the counterſcarp of the lunett is fortified by a ſort of ſmall half-moon, whoſe demigorges taken upon this counterſcarp are allowed 10 fathoms, and the faces 12 fathoms; the foſsè thereof is five or ſix fathoms broad, and is parallel to its faces. The defence of this work is taken from the ſhort faces of the lunett.

2. To deſcribe the ſmall lunett upon each face of a
Fig. 4. half-moon, at the re-entering angle E of the counterſcarp, take 15 fathoms from E to C and from E to B, for the demigorges; then for its faces from the points C and B, taken as centers, with an interval of 20 fathoms, deſcribe an interſection at D, and join B D, C D; repeat this conſtruction on the other ſide of the half-moon A, and you will have compleated the two ſmall lunetts G and H. Draw only a parapet parallel to their faces, with a foſsè ſix fathoms broad. This work is flanked by the faces of the half-moon and thoſe of the baſtion. When the half-moon is taken by the beſiegers, the foſsè before the face D C of the lunett is not flanked from any part of the place, and may ſerve to cover the enemy. Moreover as this work is leſs raiſed than the half-moon, it is therefore commanded from thence; this obliges the beſieged to leave it immediately after the taking of the half-moon. Thus two conſiderable faults are obſerved in the ſtructure of the ſmall lunetts, which is ſufficient to prevent their ever being brought into practice.

The ſame imperfections likewiſe attend the little half-moon K, deſcribed at the re-entring angle of the counterſcarp of the great lunett.

To deſcribe a counter-guard.

THE counter-guard is a work that covers the faces of a baſtion, for which reaſon ſome authors have alſo named it *cover-face.* It conſiſts of two faces that form a ſaillant angle before the flanked angle of the baſtion. Fig. 2.

For the ſtructure of a counter-guard before a baſtion X, the half-moons 4 and 5 adjacent to this baſtion being traced with their foſsès, take upon their counterſcarp the parts A D, T V, each of them 16 fathoms; and from the points D and V draw the two lines D C, C V, parallel to A G, S T, which is the counterſcarp of the faces of the baſtion X. Theſe two parallels will interſect each other at the point C, and form the ſaillant angle of the counter-guard, whoſe faces are repreſented by the lines C D, C V, they are flanked by the faces of the adjacent half-moons, but formerly had flancs of their own, which have been aboliſhed becauſe the beſiegers, when maſters of this work, uſed to batter the half-moons from thence.

The uſe of the counter-guard is not only to cover the baſtion before which it was raiſed, but likewiſe the flancs of the oppoſite and flanking baſtions, ſo that the enemy muſt be lodged therein in order to diſcover them.

To deſcribe a horn-work.

THE horn-work is compoſed of two long ſides and a front of fortification, *viz.* of a curtin and two half-baſtions. This out-work is ſometimes placed before a baſtion, but moſt commonly before the curtin. Fig. 5.

To trace a horn-work before a curtin E F, the perpendicular that was made to fall inwards from the exterior ſide for the lines of defence muſt be prolonged indefinitely towards the field, and from the re-entering angle Q of the counterſcarp take upon this perpendicular Q L 120 or 125 fathoms, and at the point L raiſe the perpendicular O P, prolonged on either ſide the point L. Upon the line O P ſet off L O and L P 60 or 70 fathoms each; then mark the points A and B upon the faces of the baſtions, at ſix fathoms diſtance from the angles of the ſhoulder C and D, and through the points O and A, P and B, draw the right lines O M, and P N, which muſt be determined at the points M and N, by their interſection with the counterſcarp of the place. Theſe lines are the wings or long ſides of the horn-work and O P is deſigned for the exterior ſide of this work. It is to be fortified by taking upon the perpendicular L Q, L R, of 18 fathoms, if you have made L P 70 fathoms; which if only 60 fathoms, L R muſt not exceed 15 fathoms. Then from the points O and P, and through the point R, draw the lines of defence O X, P V, upon which take the faces O T and P S 40 fathoms each if L P meaſures 70 fathoms, and only 35 fathoms if L P is not more than 60 fathoms. Then finiſh the flancs and curtin in the ſame manner as thoſe of the body of the place.

The foſsè of the front of the horn-work is 12 fathoms broad, and is deſcribed like that of the body of the place. The foſsè of the wings is of equal breadth, and is drawn parallel to them; the rampart and parapet are deſcribed like thoſe of the half-moon.

In the ſtructure juſt now laid down, we muſt have in mind the following Conſiderations.

1. That

1. That the flanked angles O and P of the half-baſtions of the horn-work be not leſs than 60 degrees; if they did not contain 60 degrees, the exterior ſide O P muſt be made ſhorter.

2. That whatever be the length of the ſide O P, the perpendicular L R muſt always be about the eighth part of the ſame ſide, and two ſevenths thereof muſt be given to the faces.

3. The *wings*, *long ſides*, or *branches* of the horn-work (for they bear theſe three names) are flanked by the faces of the baſtions whereon they fall; the front of it defends it ſelf, as evidently appears from its diſpoſition.

4. Beſides the horn-work raiſed before the curtin E F of the body of the place, there is made a half-moon Y, as before the other curtins.

5. To render the horn-work of greater ſtrength, two retrenchments, 1 and 2, are made therein; to trace them, raiſe perpendiculars upon the middle of each face of the half-moon, which prolong to meet the long ſides of the horn-work; theſe lines being drawn, repreſent the exterior ſides of the retrenchments; they have a rampart and parapet like thoſe of the horn-work; without, and parallel to theſe lines, make a foſsè five or ſix fathoms which is to communicate with the foſsè of the half-moon, and is flanked by its faces.

6. Before the curtin of the horn-work is generally made a half-moon; it is deſcribed in the ſame manner as that which covers the curtin of the body of the place; its foſsè is ſeven or eight fathoms broad, and is parallel to the faces.

To deſcribe a horn-work before the flanked angle of a baſtion.

PROLONG outwards and indefinitely the capital of the baſtion X, and from the flanked angle C take
Fig. 7. about 100 fathoms for the line CD; at the point D draw the line ADB at right angles with the line CD; give to DA and DB each 70 fathoms; make DE the ſixth part of the front AB, or 23 fathoms; from the points A and B, and through the point E, draw the lines of defence indefinitely; take two ſevenths of the ſide AB, or 40 fathoms, for the faces of the half-baſtions of this work, the flancs and curtin are finiſhed as in the former.

For the wings of this work, mark the points F and G upon the faces of the collateral half-moons 1 and 2, at the diſtance of 15 ~~fathoms from the angles H and K~~; then from the points A and B, in the ſame direction with AF and BG, draw the wings AL and BM to fall upon the counterſcarp of the half-moons 1 and 2.

The rampart, parapet, and foſsè, the ſame as for the horn-work before the curtin.

In this ſtructure is to be obſerved,

1. That the wings of the work are flanked by the parts NF, GO, of the half-moons 1 and 2.

2. That the wings might have been flanked by the faces of the baſtions X, but this would have rendered the angles of the half-baſtions too acute, and the defence of thoſe wings too oblique.

3. A horn-work placed before a baſtion may alſo be flanked from the curtins which are on each ſide the baſtion cover'd by the horn-work; but then the front of it muſt not extend ſo far out in the field, becauſe the angles

A and B muſt be within muſquet-ſhot of the parts which flank them.

4. Whenever the wings of a horn-work are drawn nearer to each other towards the place, than they are at the front, it is called a *ſwallow's tail*; and if occaſion requires that they ſhould be made more diſtant from each other at their extremities towards the place than at the front, it is then ſaid to be a *ſwallow's tail reverſed*.

To deſcribe a crown-work.

THE crown-work conſiſts of two fronts of fortification, having an entire baſtion betwixt two curtins and two half-baſtions, upon the wings, which are the ſame as for the horn-work. It is placed before the curtin, and likewiſe before the baſtion, as occaſion requires.

To trace a crown-work, before the curtin A B prolong indefinitely towards the field the perpendicular that ſerved Fig. 6.
for the ſtructure of the body of the place, and from the point L (the re-entering angle of the counterſcarp) as center with an interval of 140 fathoms, deſcribe an indefinite arch H K I, which will be interſected at the point K by the perpendicular prolonged. Then the point K being taken as center, with an interval of 120 fathoms, interſect the great arch at the two points H and I, and draw the right lines K H, K I, for the exterior ſides of the crown-work, which are fortified in the ſame manner as that of the hornwork; only obſerving to allow 20 fathoms for the perpendicular raiſed upon each exterior ſide, this makes it a ſixth part thereof; for the faces of the baſtion, and of the two collateral half-baſtions, two ſevenths are given, or 35 fathoms; for the wings of this work, mark the two points C and D upon the faces of thoſe baſtions before which

which it is raiſed; at the diſtance of ten fathoms from the angles of the ſhoulders E and F, in the directions of CH, DI, draw the right lines HM and IN, and theſe will be the wings; the points M and N fall upon the counterſcarp of the place.

There may be raiſed before each front half-moons O, O, as practiſed for the front of the horn-work.

A crown-work deſigned to be raiſed before a baſtion is traced by prolonging the capital 130 or 140 fathoms, and from the flanked angle of that baſtion, taken as center, with a radius of 130 or 140 fathoms, deſcribing an indefinite arch to interſect the capital prolonged; then on each ſide the point of interſection, with an interval of 120 fathoms, mark out the angular points of the two half-baſtions, and trace the two exterior ſides which fortify accordingly.

The extremities of the wings fall upon the counterſcarp of the faces of the baſtion in the direction of a point marked out upon the faces at 15 or 16 fathoms diſtance from the angles of the ſhoulder; what remains is finiſhed as above for the crown-work before the curtin.

In the ſtructure of the foregoing work we muſt obſerve,

1. That the two fronts are capable of defending themſelves, and that the wings are flanked by the faces of the baſtions.

2. That the angles of the half-baſtions muſt not be leſs than 60 degrees. If they are found too acute in the ſtructure of a crown-work before a baſtion by making the wings to fall upon the faces of that baſtion, they muſt be directed to fall upon the faces of the collateral half-moons.

3. The point K, or flanked angles of the entire baſtion, might be advanced much further out in the field, which ſome-

ſometimes is neceſſary for the incloſing within the work a greater extent of ground. But to determine how far the point K may be allowed to advance, draw the line H I, which will be divided into two equal parts at the point R by the perpendicular L K; then make the interval from R to S upon the perpendicular, equal to R H or R I, and the point S is the furtheſt that the flanked angle of the entire baſtion can be allowed to advance. Thus any point that is contained betwixt S and K may be taken for the angular point of that baſtion, which let us ſuppoſe to be T, and draw the lines S H and T H, or either of them, for one of the fronts, which fortify as uſual; obſerving, that if the point S is fixed upon , or any other betwixt S and the point T, which divides S K into two equal parts, the perpendicular made uſe of to fortify the exterior ſides of the crown-work muſt be only equal to an eighth part of the exterior ſide. If the point T, or any other betwixt T and K, is fixed upon for the angular point of the entire baſtion, then the perpendicular muſt be equal to a ſeventh part of the exterior ſide.

The flancs of horn-works and of crown-works may be deſcribed concave with orillons, in the ſame manner as was given for the flancs of the body of the place.

Having ſurrounded a fortified place with the outworks that were judged neceſſary to add, the covert way, with its glacis, muſt laſtly be traced round the counterſcarp of the moſt exterior works, in the manner that has already been laid down.

Of traverſes, redoubts, and bonnets, and of the advanced foſsè.

TRAVERSES are parapets of earth made acroſs the covert way at certain diſtances. Their length is the entire breadth of the covert way, and they are three fathoms broad, and ſix feet and a half high, including the height of the banquet. It is always made on that ſide of
Fig. 8. the traverſe which is towards the re-entring angle of the counterſcarp. Their height on the other ſide towards the faillant angles is only four feet and a half. Thus they have a ſuperior talus of two feet.

The traverſes raiſed at the faillant angles are deſcribed, by the parapet of the faces of the baſtions or half-moons being prolonged. Thoſe at the re-entring angles are traced by raiſing a perpendicular from the extremity of each face of the place of arms upon the counterſcarp, or by making them parallel to the traverſes at the faillant angles. The line that afterwards determines the breadth or thickneſs of theſe works at the place of arms is not to fall within it, but exterior to the perpendicular from the extremity of each face.

Betwixt the traverſe and the parapet of the covert way, there is a ſpace three or four feet broad for the paſſing and repaſſing of the ſoldiers; but that this paſſage may not be enfiladed, there are three different methods uſed to cover it, the firſt of which we prefer.

The firſt is, when the paſſage is cut in the parapet of the covert way to make two turnings one before the other
Fig. 9. behind the traverſe, as repreſented by the figure C.

The ſecond, wherein the paſſage is taken from the traverſe, and not in the parapet of the covert way, is cover'd by

by bringing forward in the covert way before the traverſe a merlon, as deſcribed in figure B.

The third is, to make one turning before the traverſe, and join by a right line the exterior extremity of that turning the moſt remote from the re-entring angle, to the interior extremity of the turning that is nearer to it, as is ſhewn by figure A. The *French* have called this laſt manner of covering traverſes, *Cremilliere*, from the reſemblance the figure it gives to the parapet of the covert way bears to a pot-hanger.

There is no banquet given to the covert way in theſe paſſages. The breadth of thoſe traverſes at the ſaillant angles ought not to be equal to that allowed thoſe in the re-entring angles; it ought to be only half, otherwiſe they ſerve the beſiegers for epaulements after they are become maſters of the ſaillant angles; whereas were they only nine or ten feet, and liable to be overthrown by the cannon of the beſieged, the enemy muſt be more cautious in making his lodgment, or ſuffer greatly for his raſh attempt.

M. *Herbort*, a *German* engineer, in his treatiſe of *fortifications*, written in *French*, and printed at *Augsburgh* in 1735, making mention of the covert way with the traverſes as commonly traced out, ſays, Fig. 10.

" I have often wonder'd that the covert way has been
" ſo much neglected, without any one's endeavouring to
" make it ſtronger in itſelf than hitherto has been brought
" into practice, ſince in moſt ſieges the covert way, tho'
" of ever ſo weak a ſtructure, has given the greateſt
" trouble to the beſiegers in their attack; conſidering then
" the great uſe and advantage that this part of the fortifi-
" cations, even without any additional ſtrength, are to
" the beſieged, what might not be expected if its faults
" were corrected, and its ſtrength increaſed? for this reaſon

" I was perſuaded it would not be thought unprofitable " if I had a particular attention to ſtudy how much its " ſtrength and defence could be improved.

" I duly conſidered the faults of it, as commonly de- " ſcribed, *viz.* 1. That as ſoon as the beſiegers were ad- " vanced upon the glacis at the ſaillant angles, as at *a*, " they can enfilade both the branches *b c*, *b c*, and hereby " oblige the beſieged to move off. 2. The manner " wherein the paliſades are diſpoſed; the beſiegers have " always found means either to drive away or deſtroy " thoſe who were in the covert way by the ſplinters, and " ſo leap into it by main force. 3. Whenever the be- " ſiegers were near enough to throw granadoes into the " covert way, they proved exceeding troubleſome, and " deſtructive. 4. Becauſe the covert way of itſelf afforded " no ſupport, nor any ſafe places to retire in, and the " enemy having ~~an eaſy and fair opportunity~~ to intermix " with the beſieged, and thus prevent the fire of the " works againſt them, often became maſters of it ſword in " hand without any great oppoſition. And 5thly, The " beſiegers having gained one of the ſaillant angles, be- " come maſters of all the others; for the beſieged are " left deſtitute of any ſafe retreat, or of any part wherein " they could intrench and maintain themſelves.

" To remedy all theſe inconveniencies, 1. Inſtead of " five or ſix fathoms for the breadth of the covert way, I " make it twelve fathoms broad, to give a ſufficient ſpace " for the intrenchments. 2. I make uſe, with great ad- " vantage, of Mr. *Coehorn*'s paliſades; (we ſhall have oc- " caſion to mention them in a following part of this " treatiſe. 3. I likewiſe make uſe of the leſſer place of " arms *d*, not only to ſupport the great place of arms, " but alſo for a retreat. 4. To theſe improvements I add

" a

" a covered caponiere or coffer *f*, upon the diagonals of " the ſaillant angles of the covert way, whoſe diſpoſition " ſecures the branches againſt any enfilades; beyond it I " make an exterior ſaillant angle, with a place of arms, " which covers the extremity of the caponiere and ſepa- " rates it intirely from the covert way, and gives a fire " from the line *a y*, in caſe the enemy did attack any other " part than the ſaillant angle. 5. I place paliſades upon " the counterſcarp along the line *h i*, to prevent the be- " ſiegers ſeeing the beſieged in the rear from the glacis of " the oppoſite branch of the covert way." For a more particular account of this ſtructure, we refer the curious to this book, wherein is laid down a larger plan, with the profil.

Traverſes are alſo made upon the capitals of baſtions, or of any other outwork againſt a dangerous command- ment; this intention is alſo anſwered by raiſing the ram- part and parapets higher at the point of the work, or at any other part as occaſion requires.

Traverſes greatly prevent the effect of *ricochet-batteries*. Theſe are batteries whoſe cannon is only loaded with a quantity of powder ſufficient to carry the ball in the di- rection of the faces and flancs, *&c.* of the works which are attacked; the ball thus expelled with no proportion- able force, ſoon meets the ground, and rolls and bounds thereon to the great deſtruction of all thoſe who ſtand in the direction of its courſe; it occaſions much more diſor- der, and proves more fatal being ſhot in this manner, than it would if the cannon was loaded with the full charge of powder.

M. *De Vauban* invented the ricochet, and made uſe of it at the ſiege of *Ath*, in the year 1697. The quantity of gunpowder neceſſary for the ricochet is only found out by

by repeated trials upon the ſpot, and by theſe alone the gunners are able to judge which beſt ſuits their diſtances.

Beyond the exterior border of the glacis, at the re-entring and ſaillant angles, oftentimes are made other works, with an advanced foſsè and an advanced covert way; they are intended to keep the enemy at a greater diſtance, and prolong the time of a ſiege, and if properly diſpoſed add
Fig. 11. greatly to the ſtrength of the place.

The firſt we ſhall mention are *redoubts*, alſo called *bonnets*; theſe are made of earth or of maſonry, *&c.* ſometimes vaulted, bomb-proof, as thoſe at *Luxemburgh*. Their gorges is a right line, and is 10 or 15 fathoms long. Their flanks, which are raiſed perpendicular upon the gorges are 10 fathoms, and their faces are 12 or 15 fathoms.

They have a parapet three fathoms broad, ſix or ſeven feet high, ~~with one or two banquets. Their foſsè is three~~ or four fathoms broad, and beyond it they ſometimes have a covert way, as deſcribed in the figure.

Fig. 12. The communication theſe redoubts have with the covert way is by a trench cut in the glacis, and that theſe trenches may not be expoſed to enfilades, they are ſecured by traverſes, and their entrance into the covert way oppoſed by a ſtrong barrier that opens and ſhuts.

As for the half-moons, they are chiefly traced before
Fig. 13. the re-entring angle of the covert way. Having made your advanced foſsè with the *arrows* X at the ſaillant angles, parallel to the exterior border of the glacis, and 10 or 12 fathoms broad, give 20 or 30 fathoms for their capitals, and 30 or 35 for the length of each face, which is to be ſurrounded by the advanced foſsè as is repreſented in the figure.

The

The parapet of the covert way is to command all theſe exterior works, and they are to be contrived ſo as not to obſtruct the fire therefrom, or ſerve for a cover to the beſiegers; to deprive them of this advantage, and to diſhearten them the more, thoſe works that will admit of it are generally countermined.

Laſtly, at a greater diſtance from the glacis there is often occaſion to raiſe ſome works of different irregular figures, Fig. 14. which are ſuited to the place they are made in, to prevent the enemy approaching by ſome ravin or hollow way, *&c.* They have a parapet, with a banquet, a foſsè, and a covert way, with paliſades and a glacis.

Of the place of arms, and of the tracing of the ſtreets, and of the public buildings in a fortified place.

WHEN the place deſigned to be fortified is not already occupied by ſome old habitation, nothing ought to be neglected that can contribute to make every part within it as regular as poſſible, *viz.* the diviſion of the ſtreets and of the houſes for the inhabitants, the ſituation of the guard-houſes, cazerns or barracks, the magazines for gunpowder, the arſenals, ſuttling and bake-houſes for the ſoldiers of the garriſon, town-houſe and dwelling-houſes for the governor and the officers of the major ſtate, and the other public edifices; all which muſt anſwer the ſeveral principal ends for which they are raiſed; we can give no better model than the plan of the ſtreets and diſpoſition of the public edifices of *New-Briſach.*

If there is a great extent of ground to be laid out, it is Fig. 15. not improper for the public conveniency to make ſeveral open places; but if there are reaſons for the contrary, there ought at leaſt to be one in the center, and that ſhould be

a ſquare. The dimenſion of it ſhould be proportioned to that of the circumference of the place, conſequently the number of the garriſon; for as this place ſerves for the parade of all the troops deſigned for garriſon duty, it muſt be made large enough for this purpoſe. Therefore for a fortification of ſix baſtions, ſuppoſing the exterior ſide 180 fathoms, it has been judged neceſſary to give to each ſide of the place of arms 40 to 45 fathoms; for one of ſeven baſtions, 55 to 60 fathoms; for one of eight baſtions, 70 to 75 fathoms; for one of nine or ten baſtions, 80 to 85 fathoms; laſtly, to one of eleven or twelve baſtions, 90 to 95 fathoms; but it is better to leave this to the diſcretion of the engineers intruſted with the execution of the plan, than to fix any particular rules.

Before each gate of the town there muſt alſo be made a ſmall place of arms, large enough for the drawing up of the *port-guards*, to prevent their being ſurprized from within; beſides, theſe places of arms at the gates are not only pleaſing to the ſight, but alſo are uſeful to diſengage the paſſage, when the carriages which are going out of the town are obliged to wait till thoſe upon the bridges are come in.

To know the number of ſoldiers that can be drawn up in order of battle upon a place of arms, find the area of the place in ſquare fathoms, then doubling this area, you will find about the number ſought; for it is ſuppoſed that the ſpace allowed to one ſoldier to ſtand upon in order of battle is half a fathom ſquare, three feet in front, and ſix feet in file.

For the tracing of the ſtreets, the principal ones muſt be drawn from the place of arms in a right line to the city-gates, and to the ramparts; but chiefly to the citadel or reduit, if there is any, that they may be enfiladed. They muſt be, as much as poſſible, perpendicular one to another,

another, that the corners of the houſes may be rectangular; their breadth is ſix fathoms, that three carriages may paſs in front, becauſe if one was ſtopped at one ſide of the ſtreet, and another at the other ſide, the third could go on between them; thus there is always room enough for people on foot or on horſeback. For the leſſer ſtreets, the breadth given to each of them is three or four fathoms.

The diſtance from a ſtreet to that which is parallel to it ought to be ſufficient for two houſes to be contained betwixt the parallels, one of which faces to one ſtreet and the other faces its parallel. The front of each houſe is five or ſix fathoms, and the depth of it ſeven or eight fathoms, with a yard betwixt two parallel houſes whoſe area is equal to that of one; thus the breadth betwixt the parallels is 21 to 24 fathoms, which affords ſpace enough for larger edifices where gardens and ſtables are required.

In towns where there are any old ſtreets, they may be left without any alteration, excepting in ſuch parts where it is abſolutely neceſſary to rectify them. The ſame is to be obſerved for the places of arms.

Beſides the guards poſted upon the great place of arms or the ſquare, and thoſe at the gates, there are other guard-houſes to be made upon the ramparts and in the outworks, that the ſafety of the town may not be expoſed by having the ſeveral guards poſted at too great a diſtance from each other. They are ſometimes made at the center or gorge of the baſtion, when it is not already taken up by a cavalier or powder magazine; and ſometimes they are placed in the middle of a curtin, eſpecially if there is at that part any ſluice, dam, or water-gate, occaſioned by an adjacent river.

As the magazines for gun-powder are to be as diſtant as poſſible from the houſes of the inhabitants, the beſt ſpot to place them in is the middle of a hollow baſtion.

The arſenal being one of the military edifices that takes up the moſt ground, it is no eaſy thing to fix its ſituation, becauſe this depends upon innumerable circumſtances which are not to be perceived till you have viſited and examined the place carefully. However, we muſt obſerve that it be ſeparated from all other buildings, as well for the ſafety of the ſtores, as not to be expoſed to any fire that might happen in its neighbourhood. If a river runs through the town, it is requiſite that the arſenal ſhould be near it for the conveniency of tranſporting the ſtores by water-carriage. The plan of an arſenal ought to be ſo contrived, that the inhabitants cannot know or perceive the buſineſs tranſacted therein, with reſpect to the ſending out of any arms, ammunition, &c.

There are ſeveral large court-yards incloſed within the exterior circumference of arſenals, wherein many edifices ſeveral ſtories high are built for various uſes. In the ground-floors are kept the cannons, mortars, bombs, balls, ropes, earth-ſacks, harneſs for the artillery-horſes, intrenching-tools, and other heavy and unwieldy machines. Above are placed the ſmaller ſort of fire-arms and others, as muskets, carbines, piſtols, pikes, halbards, ſwords, bayonets, cartouch-boxes, belts, &c. The forges and work-houſes for the carpenters, wheelwrights, black-ſmiths and gun-ſmiths, collar-makers, &c. are properly diſpoſed, with the apartments for lodging the artillery-officers, and the ſeveral workmen.

If a foundery is intended to be made in the arſenal, a proper place muſt be marked out for it.

The

The *cazerns*, or barracks, are placed along the curtins near to the rampart. This is the beſt ſituation that can be given them, becauſe the ſoldiers are by theſe means ſeparated from the towns-people, and can be immediately aſſembled with ſecrecy; whereas if they were quartered up and down the town, and any alarm happened in the night-time, it would be much more difficult to get them together.

At both the extremities of each row of cazerns are the pavilions where the officers of the garriſon are lodged.

The bake-houſes, and *cantine* or ſutling-houſes, ought to be at no great diſtance from the barracks, and near to thoſe places where there is a guard; this will prevent any diſturbances or riots ariſing.

The hoſpital muſt be built in a place apart, and the advantage of a river or rivulet running hard by it is not to be neglected, if there is one. At *New-Briſach* it is without the town, and is covered by a great crown-work.

The houſes where the officers of the major State are lodged, the town-hall, priſon, principal church, *&c.* are all built in the great place of arms or ſquare; this makes it equally convenient for the reſort of the inhabitants to any of theſe places.

The number of gates to a fortified place ought to be as few as poſſible, not to diminiſh the ſtrength of the fortifications, or increaſe the number of port-guards; for there muſt be a ſufficient guard at each gate.

The part of the rampart where the gates are generally made, is in the middle of the curtin, as it is the ſtrongeſt, being defended by the two flancs. The plan of a gate for a fortified place, conſiſts in a guard-room for the officers of the guard, and another much larger for the private men. There is alſo a room that is made uſe of as a priſon. Over the gate-way, on the exterior ſide, is made a

chamber which contains the *portcullis*; and on the interior ſide, towards the town, is a lodging-room for one of the port-captains or town-adjutants.

The plate wherein are repreſented the plan, elevation, and profil of a gate for a fortified place, and likewiſe of a guard-houſe, will give a more diſtinct notion of theſe buildings than can be done by words; therefore, notwithſtanding it regards civil architecture, we think proper not to omit it, nor any of the following, becauſe they are directly connected with the elements of fortification.

The exterior ſide of the gate-way is ſeldom ſhut in any other manner than by drawing up the draw-bridges; and if they are broken by the *petard*, or cannon, the portcullis, which riſes and falls at pleaſure, is then of great ſervice to prevent ſurprizes in the time of a ſiege.

There are two ſorts of portcullis, the one of them called *orgues*, and the other *a herſe* or *ſarazine*. The *orgues* are ſeveral pieces of timber, as many as are neceſſary for the breadth of the gateway; the interval betwixt two of them is not above half a foot; they hang perpendicular down from a cylindrical beam, to which they are faſtened ſeparately by ropes, and fall by their own weight at the looſening of a ſtay; they are afterwards wound up by a contrivance for that purpoſe; an accident happening to one or two of them is eaſily remedied, nor does it affect the others.

The *herſe* or *ſarazine* riſes or falls in the ſame manner as the *orgues*. The perpendicular pieces of timber of a herſe are not ſo thick, or ſo cloſe together, as thoſe of the *orgues*, and they are faſtened to others which are nailed acroſs them. The inconveniencies this portcullis is liable to, and which are not to be found in the firſt, are, that they can be hindred from falling by obſtructing their motion

tion in the grooves on each ſide the gate-way, or by ſetting a carpenter's horſe underneath to ſtop them in their deſcent; moreover, if it is broke by a cannon-ball, it cannot immediately be repaired.

Beſides the principal gates of a town, there are poſterns made in different parts of the rampart, as in the reverſe of an orillion, or in the curtin near the flancs, for the communication with the outworks; their paſſage is vaulted under the rampart, and is ten or twelve feet broad, but the doors are not more than four or five feet wide. Towards the foſsè they are covered or masked by ſtone or brick-work, three or four feet thick, that the exterior part of the lining appearing all alike, it cannot be diſcovered where the poſterns are made. The masked part of the lining is never broke open but in caſe of neceſſity.

The *guerites* are the ſentry-boxes, built upon the *cordon* at all the ſaillant angles of a work; for ſuch of thoſe that are lined they are made of ſtone, otherwiſe of timber. They muſt have windows on every ſide, that the ſentry within may hear and ſee any thing that paſſes in the foſsè, and not fail to give the alarm, if an enemy attempted to ſurprize the place. The figures and dimenſions of guerites, both of wood and ſtone, may be ſeen in the plate where they are deſcribed, which needs no further explanation.

The *bridges* are drawn in a plan from the gorge of the half-moon to the entrance of the gate, perpendicular upon the curtin, and from one of the faces of the half-moon to the oppoſite counterſcarp, and thus acroſs all the foſsès to the counterſcarp of the covert way. The parapet of the covert way is cut away ſufficiently to open a paſſage nine or twelve feet broad, which paſſage is ſtopped at pleaſure by a ſtrong barrier, or field-gate, made for that purpoſe.

There

There are two parts to every bridge that is made acroſs any foſsè of a fortified place, and the whole is of wood, excepting the foundation; the one fixed and unmoveable, which is called the *ſtanding-bridge*; the other moveable, and named the *draw-bridge*. It is to be obſerved that there are made two draw-bridges when the foſsè is very broad, as before a curtin, &c. the one always joining to the eſcarp, and another about the middle of the foſsè.

The draw-bridges at the gates are made to riſe by a *counterpoiſe* fixed at the ends of the chains, within the entrance of the gate-way, which is ſhut whenever the draw-bridge is drawn up; the others in the middle of the foſsè, and at all the outworks, is drawn up by chains fixed to the two *arms*, as deſcribed in the figure. The height of the piles that ſupport the bridge is determined by the depth of the foſsè.

Here follows a further explanation of the ſeveral plans and elevations of the different military edifices, &c. juſt mentioned. The ſcales that are laid down to the ſeveral figures, ſufficiently ſhew the proportions of all their parts.

PLATE 14. The diviſion of the ſtreets of *New-Briſach*.

The table of references ſhews the diſpoſition of all the public buildings, none of which are to be omitted in a fortreſs of conſequence, and fully explains every part of this plan.

PLATE 15. The plan, profil, and elevation of part of the cazerns, and of a pavilion for the officers of the garriſon.

Theſe buildings are greatly to be approved for all places where a body of ſoldiers are requiſite to be garriſoned, as in thoſe upon the borders of rivers, or upon the ſea-coaſts; alſo

alſo wherever any important conqueſt has been made. The troops thus lodged are much better diſciplined, and more regular in their manners, than if they were quartered at private houſes, where they never fail of committing the greateſt diſorders, to the ruin of many families, notwithſtanding the puniſhments inflicted on them from time to time.

Before the number of pavilions and cazerns can be fixed for any place, the number of men neceſſary for the garriſon, ſuppoſing it to be threatened with a ſiege, muſt firſt be known. M. *de Vauban* did obſerve the following rule.

If the place be regularly fortified, find out the number of baſtions; otherwiſe, the meaſure of its circumference being given, you may know the number of baſtions and outworks neceſſary to fortify it; then allow to each baſtion and ſuch outworks or outwork equivalent thereto, 500 men, infantry, and 200 horſe, *viz.* ſeven companies and four troops; thus you may find the number of officers for each baſtion. Multiply theſe numbers of private men and officers by the number of baſtions and other equivalent outworks, and the product will give the number requiſite to garriſon the place, which being known, you may regulate the extent of the building deſigned for the cazerns and pavilions in the following manner:

The ſize of the chambers for the cazerns that are deſcribed in the plan we have given, allows in each chamber four beds, therefore twelve ſoldiers can lodge in one chamber, if the place is obliged to mount very ſtrong guards, becauſe whilſt there are eight in the chambers, the other four are upon duty. Thus in a building of four rooms on a floor, and three ſtories high, 144 ſoldiers can be lodged.

The

The ground-floor of the cazerns in this plan is chiefly intended for ſtables for the troop-horſes.

The diviſion of one pavilion is in two equal parts, by a paſſage ſix feet broad, having two ſtair-caſes; each part contains four rooms on a floor, which is deſigned to lodge four officers, two in one chamber; the other two chambers is deſigned for kitchens, the ſervants lodging, &c. therefore as eight officers are lodged on the ſame floor, if the pavilion is three ſtories high, it will contain 24 officers.

We have mentioned an hoſpital for the ſoldiers to be one of the public edifices neceſſary in a fortified place, and it ought by no means to be omitted wherever there is a conſtant garriſon. The extent of building intended for this purpoſe is to be determined upon the number of ſick there may happen to be at the time that the garriſon is the moſt numerous. Experience has ſhewn us, that we may reckon one ſick man in twenty-five; however, the number muſt be ſuppoſed to increaſe or diminiſh according to the different ſeaſons, and as the air of the climate is pure and wholeſom or unwholeſom. We omitted the plan and elevation for this building, thinking it not neceſſary.

PLATE 16. The plans and profils of magazines for gun-powder, the one according to M. *Vauban*, and the other after a new conſtruction of M. *Belidor*.

Notwithſtanding the precaution that is uſed in making the loop-holes, or chinks, which admit of air to refreſh the magazine when ſhut up, in ſuch a manner ſo as to prevent any thing being introduced by hand, they ought to be further ſecured by iron grates, otherwiſe a lighted fuſe or match might be faſtened to the tail of a live rat, mouſe, or ſome ſuch ſmall animal, and being puſhed in, would anſwer the intentions of an enemy by ſetting fire

to

to the magazine. The common method of laying the floors of a powder-magazine upon joiſts which are cloſe to the earth, and whoſe intervals are filled up with bits of ſtone or brick, is not to be approved, becauſe no air can paſs under the floor, which occaſions it to be very damp, and to become rotten, to the great damage of the gunpowder.

To remedy theſe inconveniencies, the interior plinth of the foundation ſhould be raiſed one foot above the ſurface of the ground, and ſhould advance from the wall five or ſix inches; afterwards let there be laid, the whole length of the magazine, three rows of maſonry at equal diſtances, each of whoſe height and breadth ſhould be one foot; this maſonry muſt be raiſed upon a ſingle row of bricks, laid without mortar in the ground, of an equal breadth.

The maſonry being exactly levelled, and having had time to dry, the joiſts may then be laid at two feet diſtance from each other, and faſtened in the walls; then the firſt and ſecond floors may be laid as uſual. The air that will find a free paſſage through the intervals of the three rows of maſonry, will preſerve the timber uſed for the floors, joiſts, *&c.* from rotting, and the powder from being damaged by damps.

Notwithſtanding no part of the theory of vaults, *&c.* that regards civil architecture, was deſigned to be inſerted in this treatiſe, yet as it is neceſſary, in order to deſcribe them, to determine the thickneſs of the reins of vaults for magazines, ſouterreins, and other military edifices, according to their different breadths, that they may equally reſiſt the ſhock of bombs, we will not omit the following general rule given by M. *Belidor*.

Suppoſe the magazine 36 feet broad, covered by a vault whoſe ſtructure is a *ſemicircular arch*, called alſo a

perfect arch, or *plein cintre*; it is required to know the thickneſs that muſt be given to the ſtone-work of the vault in the middle of its *reins*, to render it bomb-proof: to reſolve this queſtion we muſt premiſe, that a vault with a perfect arch 25 feet broad and three feet thick, in the middle of its reins, is known by experience to be entirely bomb-proof; therefore, *if the diameter of* 25 *feet gives nine feet for the ſquare of the thickneſs of a vault that is bomb-proof, what ſquare will the diameter of* 36 *feet for another vault produce, that its thickneſs may likewiſe be bomb-proof?* It will produce 13 feet, from which extracting the ſquare root, you will have three feet, ſeven inches, and two lines, which is the thickneſs required.

The demonſtration of this rule depends upon certain principles of the mechanics, and can be found in many treatiſes upon this ſubject, to which we refer the reader.

There are two ſtrong doors for the entrance of a powder-magazine, the one inward, and the other without; the thickneſs of the wall determines the ſpace betwixt them; the outward door is covered over with iron plates, and has only one lock, whoſe key is intruſted to a keeper; the inner door has two locks with different keys, the one is kept by the governor of the place, and the other is committed to the care of the officer who commands the artillery. It is advantageous to have the doors facing the ſouth or eaſt, that the inſide of the magazine may receive the ſun-ſhine when it is opened to be aired; for this purpoſe alſo over the door, and at the oppoſite end, is made a window, ſhut by double ſhutters, faſtened with ſtrong bolts.

To every magazine at 12 feet diſtance from each of its ſides, there is a wall that ſurrounds it, to hinder any ones ap-

approaching nearer, its height is nine or ten feet, and it is one foot and a half thick.

The barrels of powder ought not to be piled more than three in height, for if there are four or five, the under ones bear too great a weight, which makes their hoops and ſides to break and open, this lets out the powder, and may be liable to very fatal accidents.

PLATE 17. The plan, profil, and elevation of a gate for a *fortified town*; alſo the plan and elevation of a guard-houſe, for the different parts of the fortifications.

PLATE 18. Several plans and elevations of ſtone and wooden guerites, together with the figures of the two portcullis.

PLATE 19. The draw-bridges and ſtanding-bridges; with the plan and piles of a little bridge of communication; and the figures of barriers or field-gates.

Of Batardeaus.

WHAT the *French* engineers term a *batardeau*, is nothing elſe than a maſſive perpendicular pile of maſonry, whoſe length is equal to the breadth of a foſsè, inundation, or of any part of a fortification where the water cannot be kept in without the raiſing of theſe ſorts of works, which are deſcribed either on the capitals prolonged of the baſtions or half-moons, or upon their faces. PLATE 20.

Its thickneſs or breadth is from 15 to 18 feet, that it may be able to withſtand the violence of the enemy's batteries.

Its height depends upon the depth of the foſsè, and upon the height of water that is neceſſary to be kept up for an inundation; but the top of this building muſt al-

ways be under the cover of the parapet of the covert way; ſo as not to be expoſed to the enemy's view.

In the middle of its length is raiſed a maſſive cylindrical turret, whoſe height exceeds the ridge of the batardeau ſix feet.

The profil ſhews that the point of the turret and the ridge are deſcribed rectangular; this is done to make them the ſtronger.

The uſe of this turret is to prevent any one of the enemy croſſing the foſsè upon the ridge to the walls of the rampart, and afterwards get into the town by the help of a ladder; it likewiſe ſerves as an obſtacle to any one of the garriſon who attempts to deſert by the ſame means.

They are alſo of uſe to prevent the communication with the river and the foſsès of a fortreſs, that might favour the enemy's attempt to ſurprize the place by ſending any detachments in boats, or barges.

Of Citadels.

CITADELS are ſmall fortifications built by order of a ſtate or prince to keep the inhabitants of a town in obedience, if there are any reaſons to ſuſpect them of proving diſloyal; and to defend them againſt an enemy, if they remain faithful to the government. PLATE 21.

Citadels, for the moſt part, are regular, and have four or five baſtions, but their number muſt never exceed ſix. If they are built upon a place where there is not a ſufficient extent, and that is naturally fortified by inacceſſible ſituations, they then become irregular.

A citadel is deſcribed upon the circumference or *enceinte* of the body of the place, part of it within and part without towards the field.

The

The town is never fortified on the ſide of the citadel, that the inhabitants may not be covered againſt the fire therefrom, and that the citadel may command the town; for theſe reaſons a citadel muſt be fortified with greater care than the town, becauſe if it was of inferior ſtrength, the enemy would attack it firſt, and being maſters of it, could eaſily reduce the town; whereas being obliged to begin by attacking the town, after it is taken, they cannot avoid a ſecond ſiege in order to take the citadel.

Betwixt the covert way of the citadel and the houſes of the town, there is left a great ſpace of 120 to 150 fathoms, void of houſes, and levelled from the extremity of the glacis, *&c.* this is called the *eſplanade*, ſo that by this precaution no approaches can be made to the citadel without being diſcovered.

Citadels are never made in the middle of a town, for ſhould the inhabitants rebel and join the enemy, they could intercept all manner of ſuccour. Sometimes a citadel is raiſed at a ſmall diſtance from the town, but then it is joined thereto by *lines*, or other works of communication.

The citadel muſt be placed upon the higheſt ground about the town, that it may be able to command all the fortifications. Its ſituation likewiſe muſt be ſuch, that it can diſpoſe at any time of the ſluices or engines which ſupply the foſsès, canals, *&c.* of the place with water, an advantage that it ought to be able to maintain after the enemy had taken the town.

The manner of tracing the plan of a citadel is as follows. Let the baſtions L E M be the ſide of the circumference whereon the citadel is deſigned to be placed. The baſtion E, together with the adjacent curtins and oppoſite flancs and face, is to be demoliſhed, and its capital prolonged

longed indefinitely within and without the circumference; then mark the point D upon the capital prolonged, nearer or more diſtant from the circumference, according to the ſituation that is fixed for the citadel; through the point D draw the line A B at right angles with the capital prolonged, and make D A, D B, 90 fathoms each; thus the line A B will contain 180 fathoms.

Suppoſe the figure of the polygon that you are to fortify for the citadel is a regular pentagon, ſeek in the table of the meaſures for the ſtructure of the body of the place, *page* 12, the great ſemi-diameter of a pentagon, the length of whoſe exterior ſide is 180 fathoms, and it will be found 152 fathoms and three feet; then from the point A and B, taken as center, and with an interval of 152 fathoms and three feet taken upon the line A B, divided into 180 equal parts for a ſcale, deſcribe two arches mutually interſecting one another at the point C, which will be the center of the citadel; from the point C deſcribe a circle with the radius C B, and therein inſcribe the four other ſides of the pentagon, each equal to A B; afterwards fortify every ſide of the pentagon, and add ſuch outworks as ſhall be thought proper; finally, from the flanked angles F and I of the baſtions L and M, draw the right lines F A and I B, to join the walls of the town to thoſe of the citadel.

If it was deſired to deſcribe a citadel with an entire baſtion within the circumference of the town, the capital of that baſtion muſt coincide with the line C D, and the flanked angle with the point D; then on making D C equal to the great ſemi-diameter of a pentagon, according to the meaſures juſt now mentioned, deſcribe a circle with the radius D C, and therein inſcribe the pentagon, which fortify as before.

Citadels

Citadels are joined to the fortifications of a town in various manners, according as the ſituations of the town and of the citadel will admit; but in whatſoever manner this is done, there muſt be no one part of the fortifications of the body of the place, nor of any of its out-works, which can either batter or command the citadel. The lines F A and I B, which were drawn to join the circumference of the town to the ramparts of the citadel, are called *lines of communication*; theſe lines ſometimes fall upon the flanked angles of the baſtions of the citadel, and ſometimes upon the middle of its curtins; this laſt direction is to be preferred.

Theſe lines of communication have the ſame ſtructure as a batardeau, their thickneſs is the ſame, and their length is determined by the breadth of the foſsè wherein they are raiſed; at the bottom, in the middle of the foſsè, is opened a ſmall paſſage two feet ſquare, either for the waters of the foſsè or of the cuvett, if there is one, which is ſecured by an iron grate.

There are ſeldom more than two gates to a citadel, one towards the town, and the other towards the field, this laſt is never opened but to receive reinforcements of ſtores, ammunition, or troops, for which reaſon it is called, *the gate of ſuccour*; out of this gate any detachment from the garriſon can be ſent upon ſervice, if it is judged neceſſary, and that the enemy had taken the town by ſurprize.

Whenever towns are large and populous, there is made a *reduit* on the ſide of the circumference oppoſite to that whereon the citadel is placed; this is generally a baſtion, whoſe gorge is fortified by deſcribing a ſmall front of fortification, with a foſsè and eſplanade. PLATE 22.

The

The baſtion that is intended for a reduit muſt be ſtrongly fortified towards the field, otherwiſe the enemy would attack it, and having taken it, could make uſe of it againſt the town, which is quite expoſed to the fire of the reduit. Theſe ſort of reduits have been practiſed at *Straſburgh*, *Liſle*, &c.

When the town is not large enough to admit of a citadel, then only a reduit is made, which anſwers the ſame purpoſes, as at *Landaw*.

Citadels deſigned for ſuch places as are ſituated upon the border of a river, or upon the ſea-coaſt, muſt be diſpoſed ſo as to command the town, the harbour, and the land.

We have hitherto treated of the regular ſtructure of all ſorts of works which are eſſential in the fortification of a place. There remains to ſay ſomething of thoſe made under ground, for the further ſecurity of the beſieged, and to the great diſcouragement of the beſiegers, notwithſtanding their ſuperiority of numbers. We mean to ſpeak of *countermines*, but as this ſubject is immediately connected with that of *mines*, it will be more proper to inſert them together, which we ſhall do in treating of the *attack and defence* of places, and ſhall only take notice of ſouterrains, called alſo *cazemates*.

Of Souterrains.

BY ſouterrain or cazemate is underſtood any vaulted place that is made under the ramparts of a fortreſs, as poſterns, which ſerve to admit of a communication with the out-works; alſo magazines, mentioned in a former ſection, that are made in full baſtions; or any other place that

The Tracing of the Ou

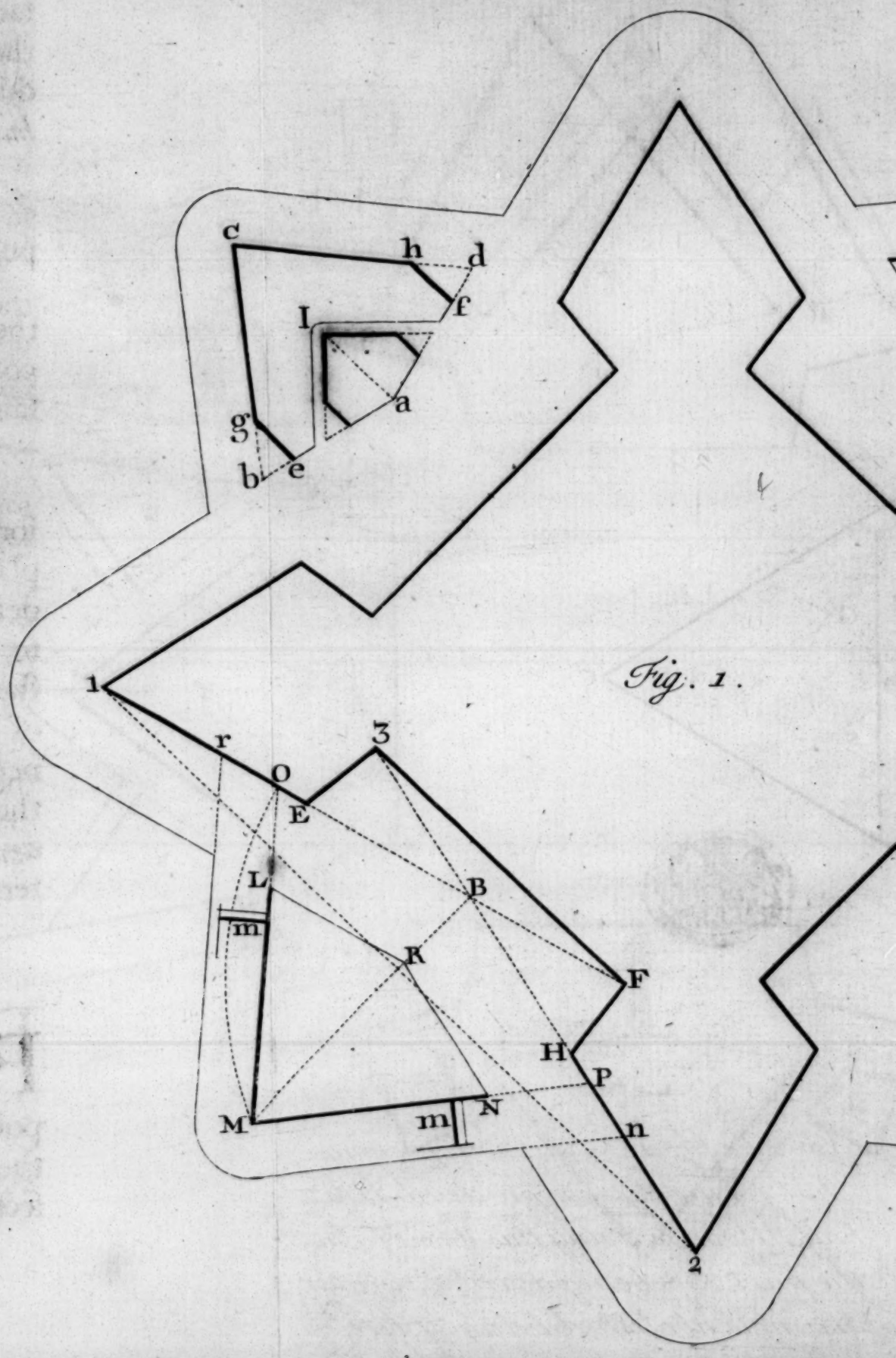


Fig. 1.

The fifteen plates Numbers 9 to 23 are to be placed at page 80.

e of the Out-Works.

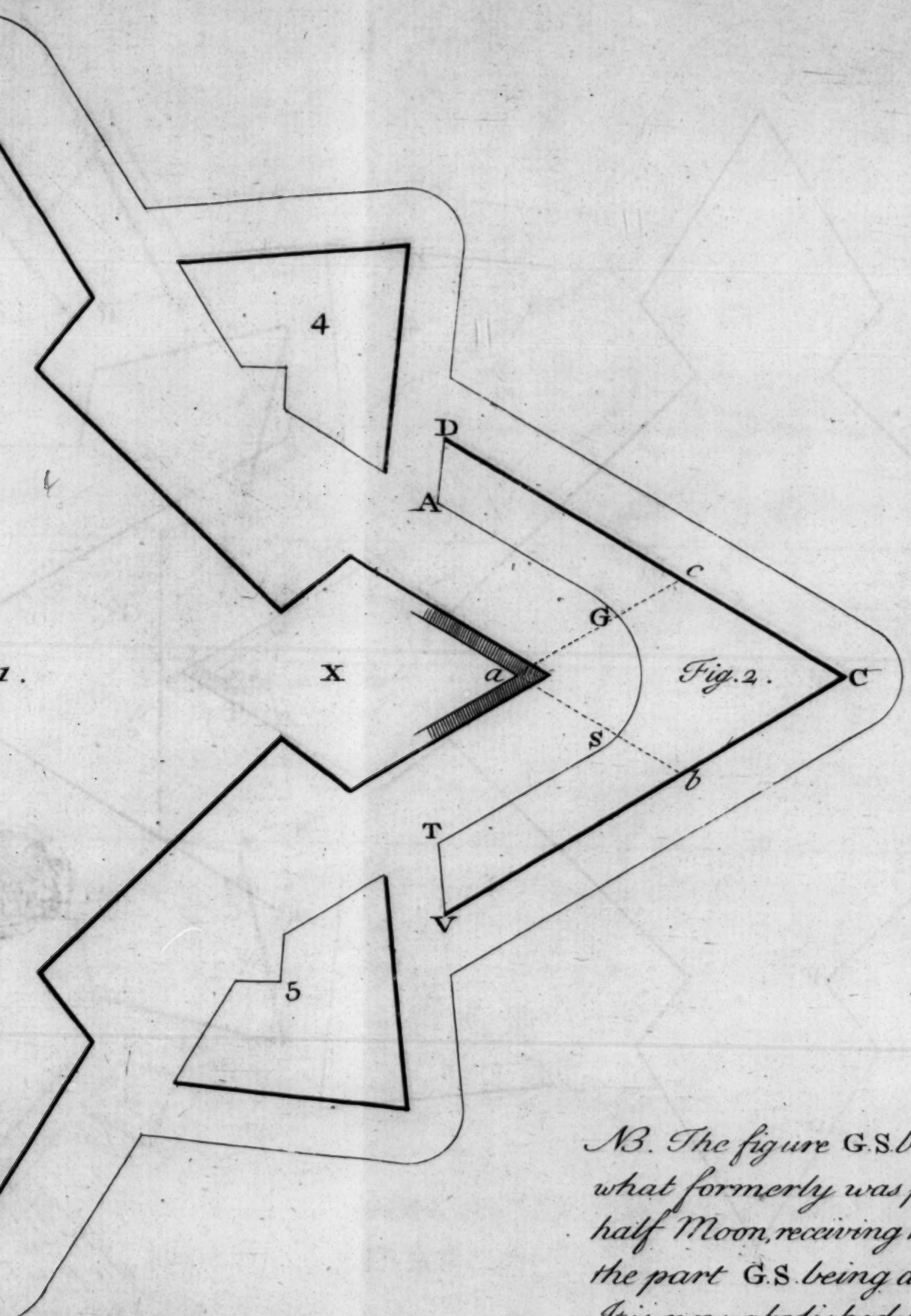
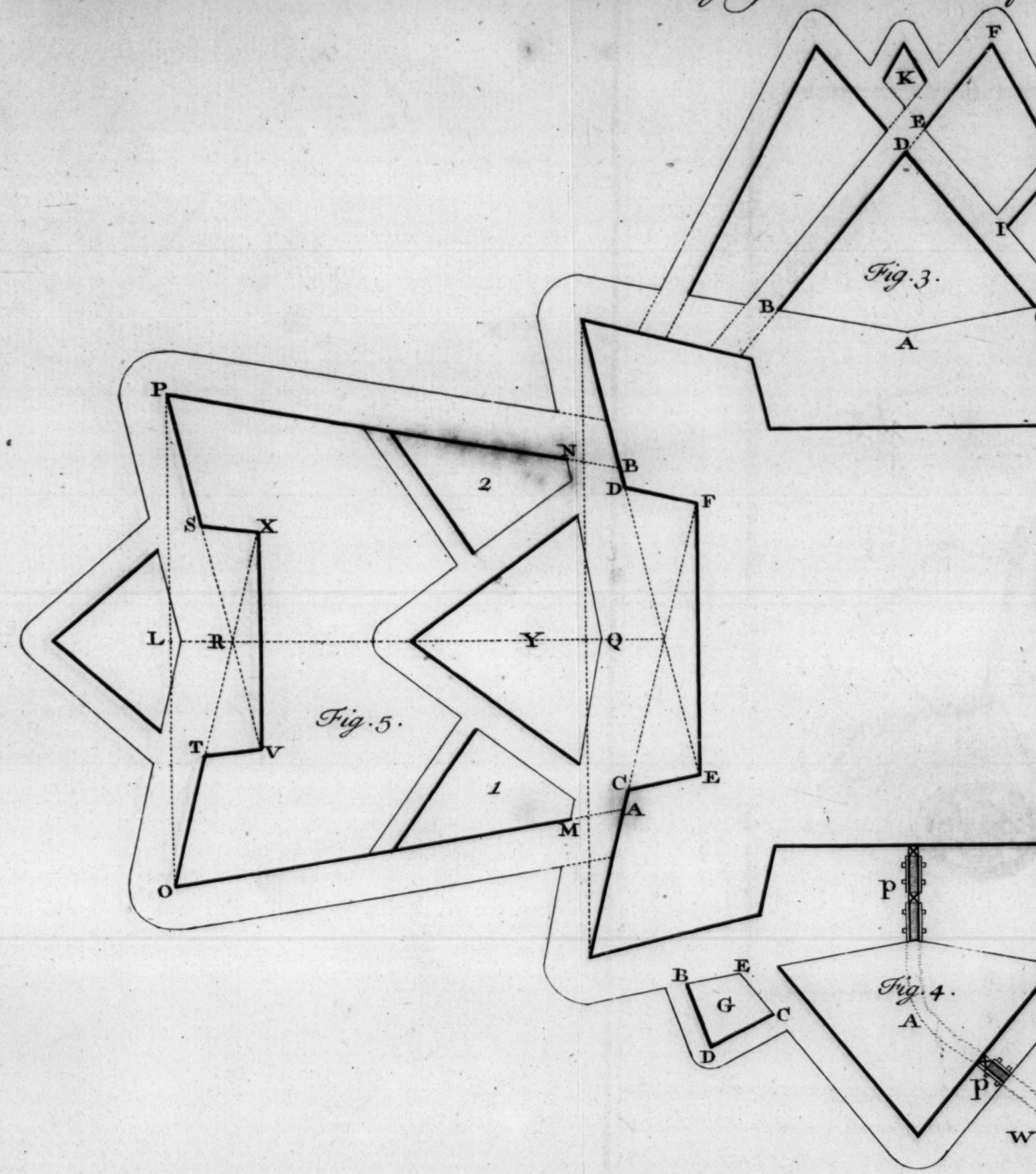


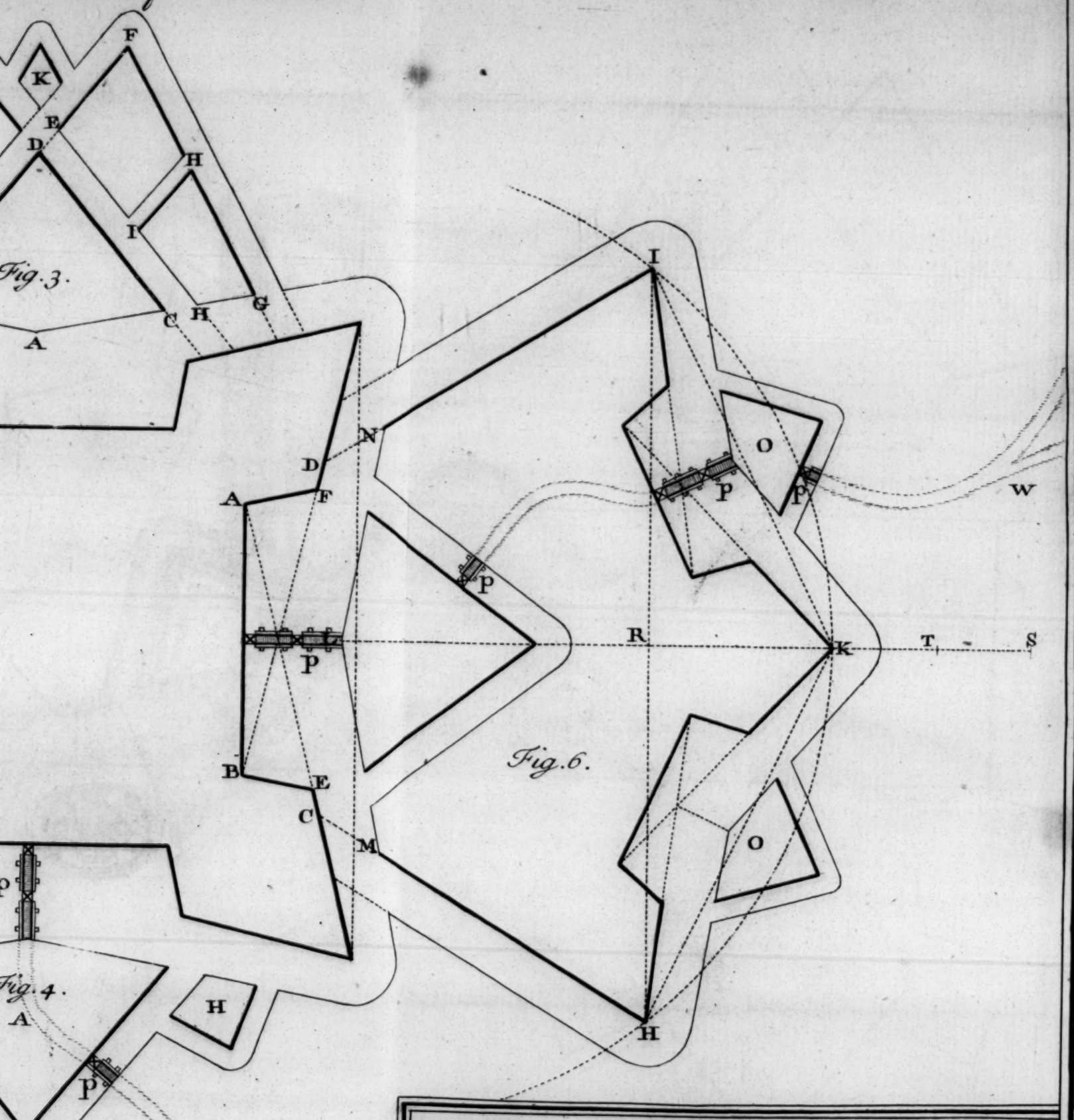
Fig. 2.

NB. The figure G.S.b.C.c. represents what formerly was practised as a half Moon, receiving this Name from the part G.S. being described circular It is now abolished being of little Signification and not well defended.

The Tracing of Several Sorts of

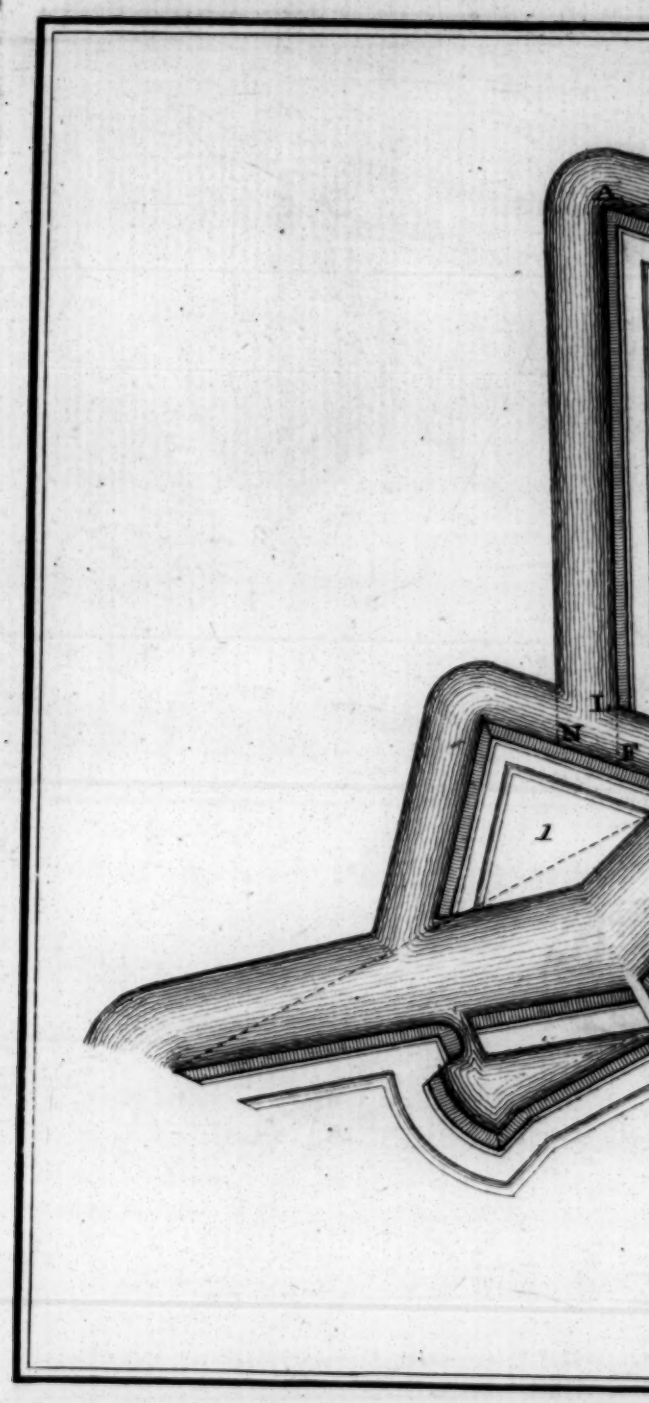


ral Sorts of Out-Works.



P.P.P.P.P.P.P. *Shew how the bridges over the Fosses of a Fortified Town are Described in a Plan, The Draw-bridges are represented by a Cross as* ⊠

W.W.W. *The manner to Describe the roads in a Plan*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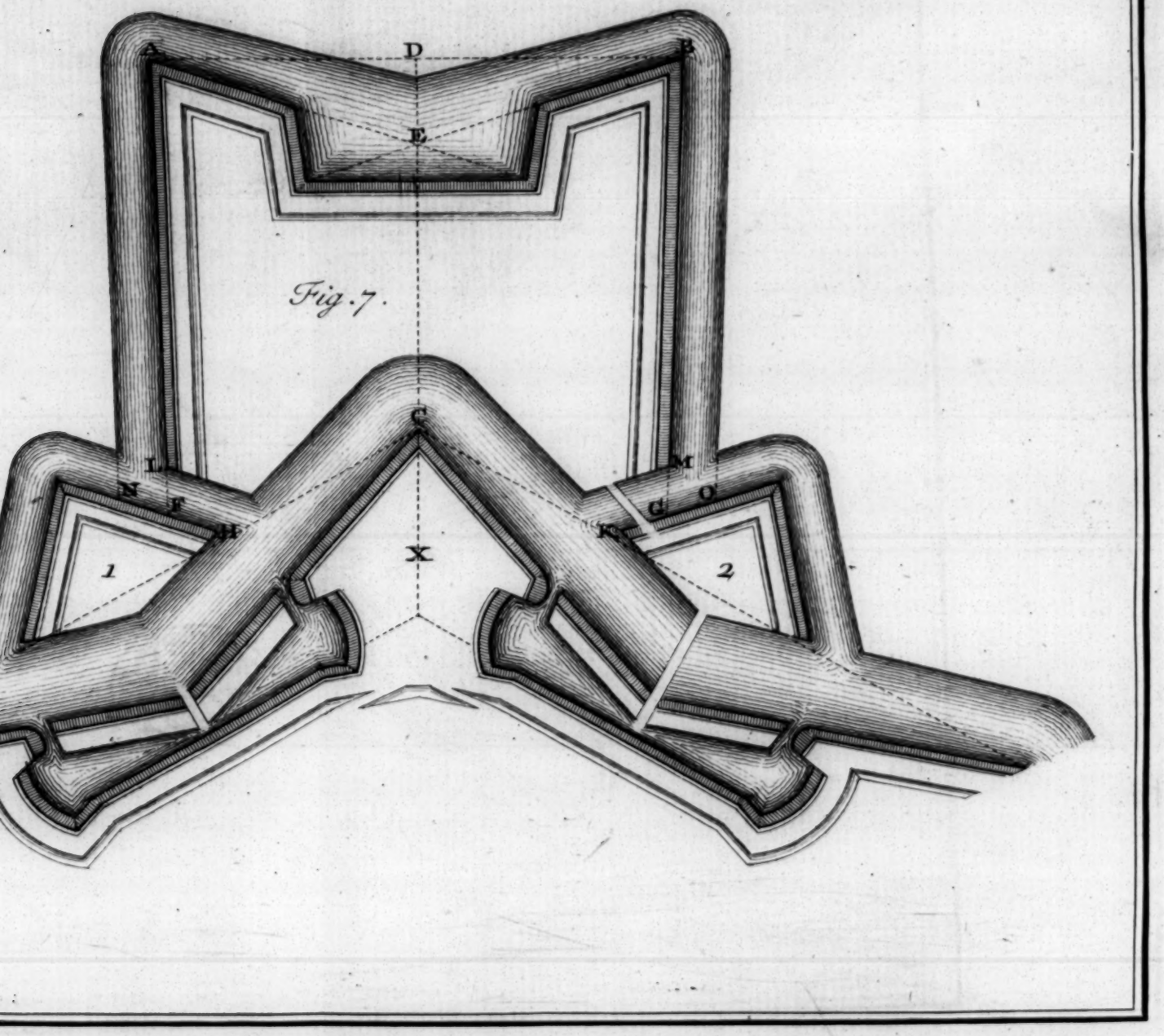


Fig. 7.

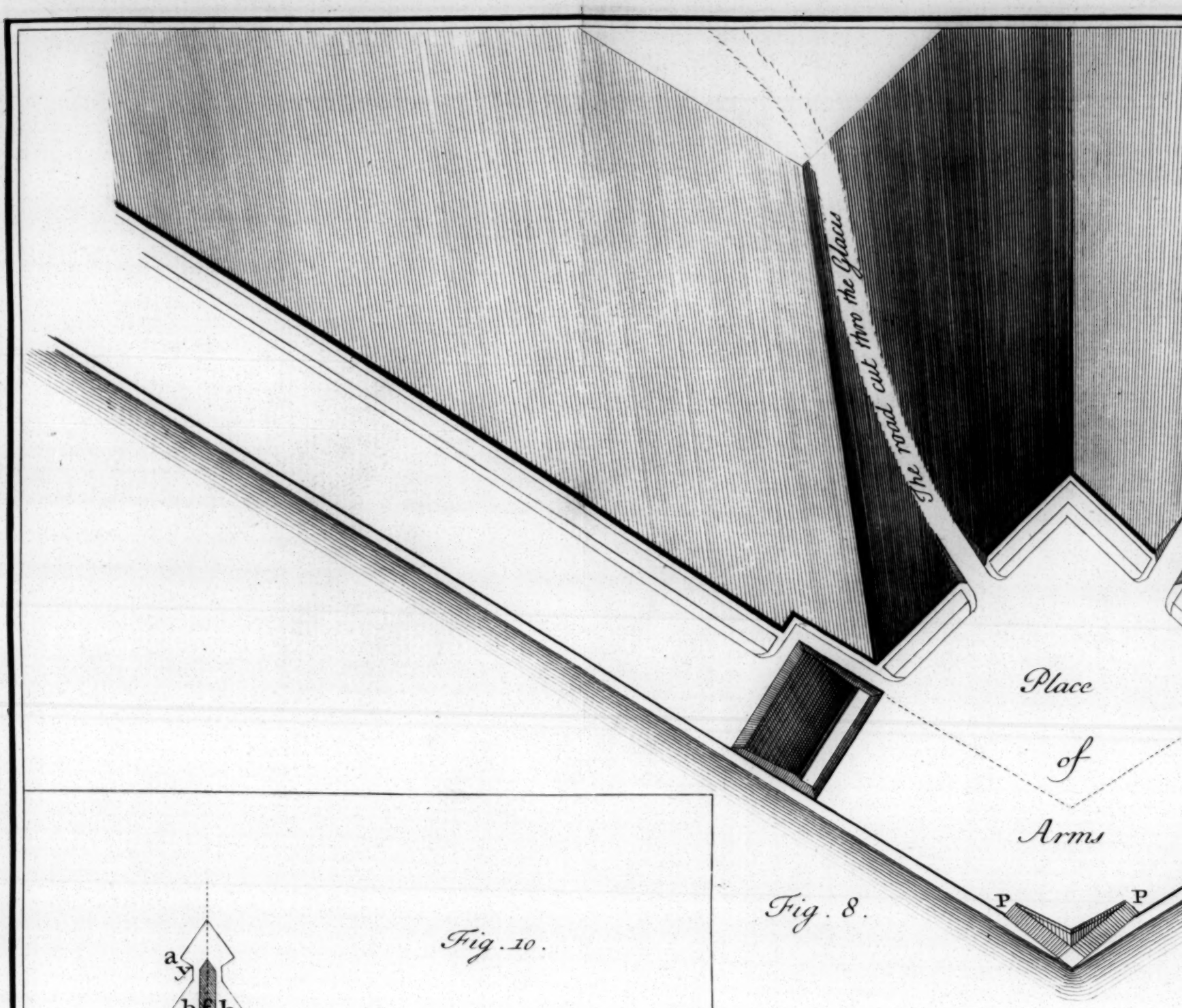


Fig. 8.

A Scale of 30 Fathoms
5
10

P.P. The Steps to descend into the
made at the re-entring Angles &
the Counterscarp before the Points

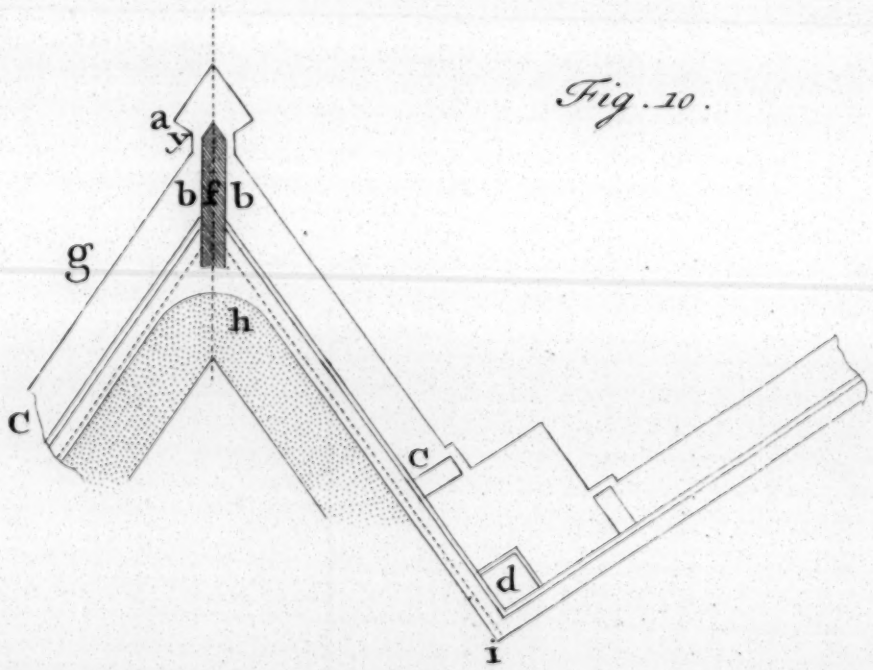
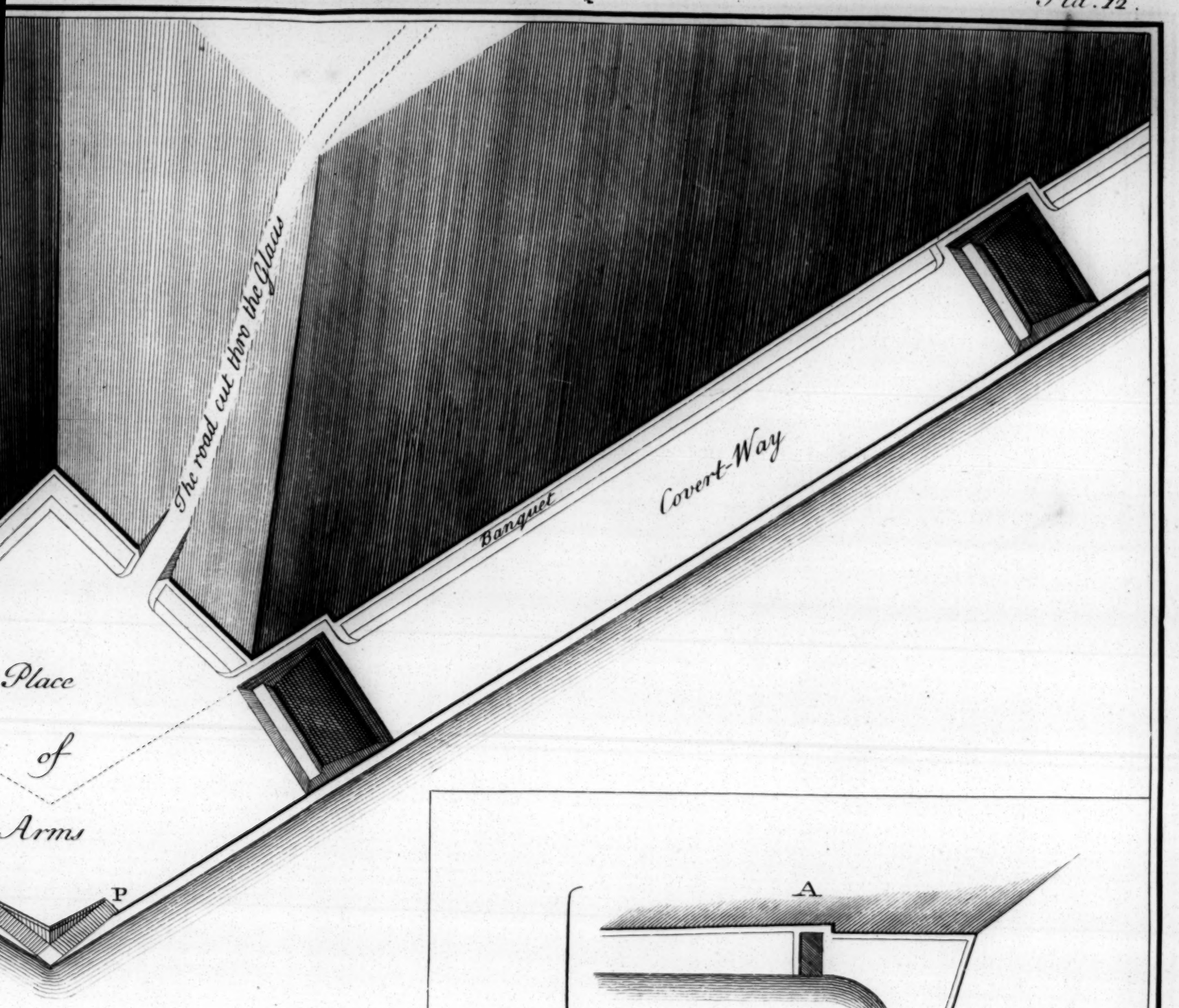


Fig. 10.



30 Fathoms for Fig. 8

20 30

end into the fossè they are
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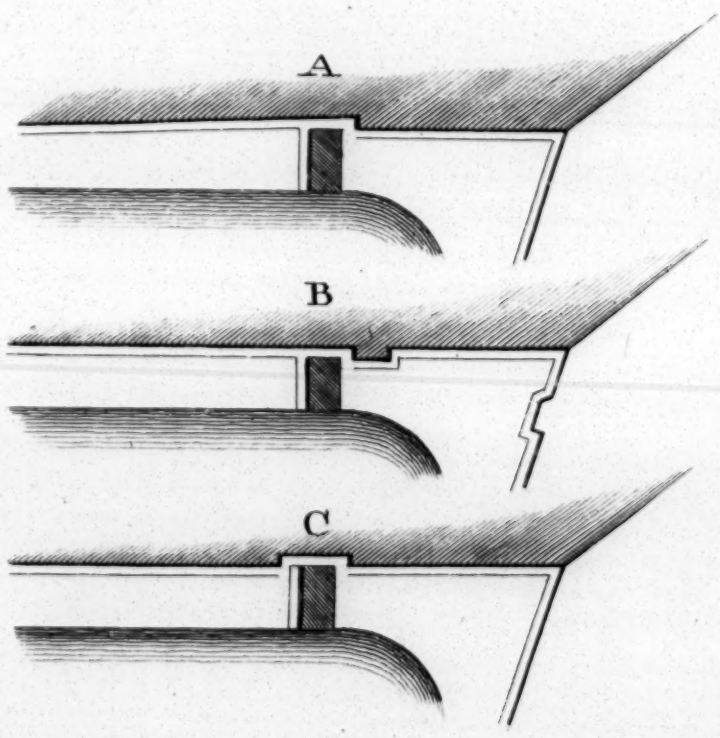
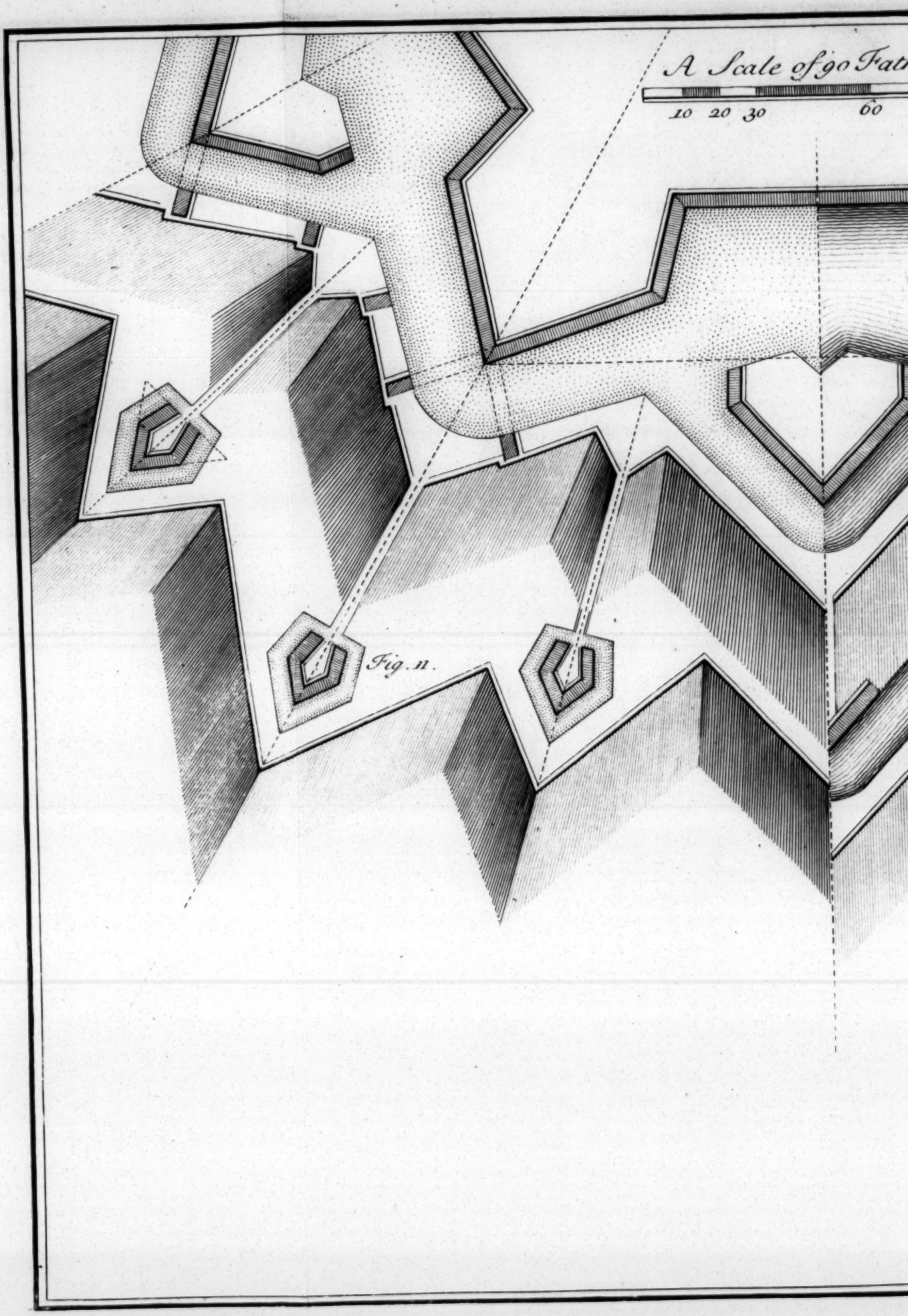
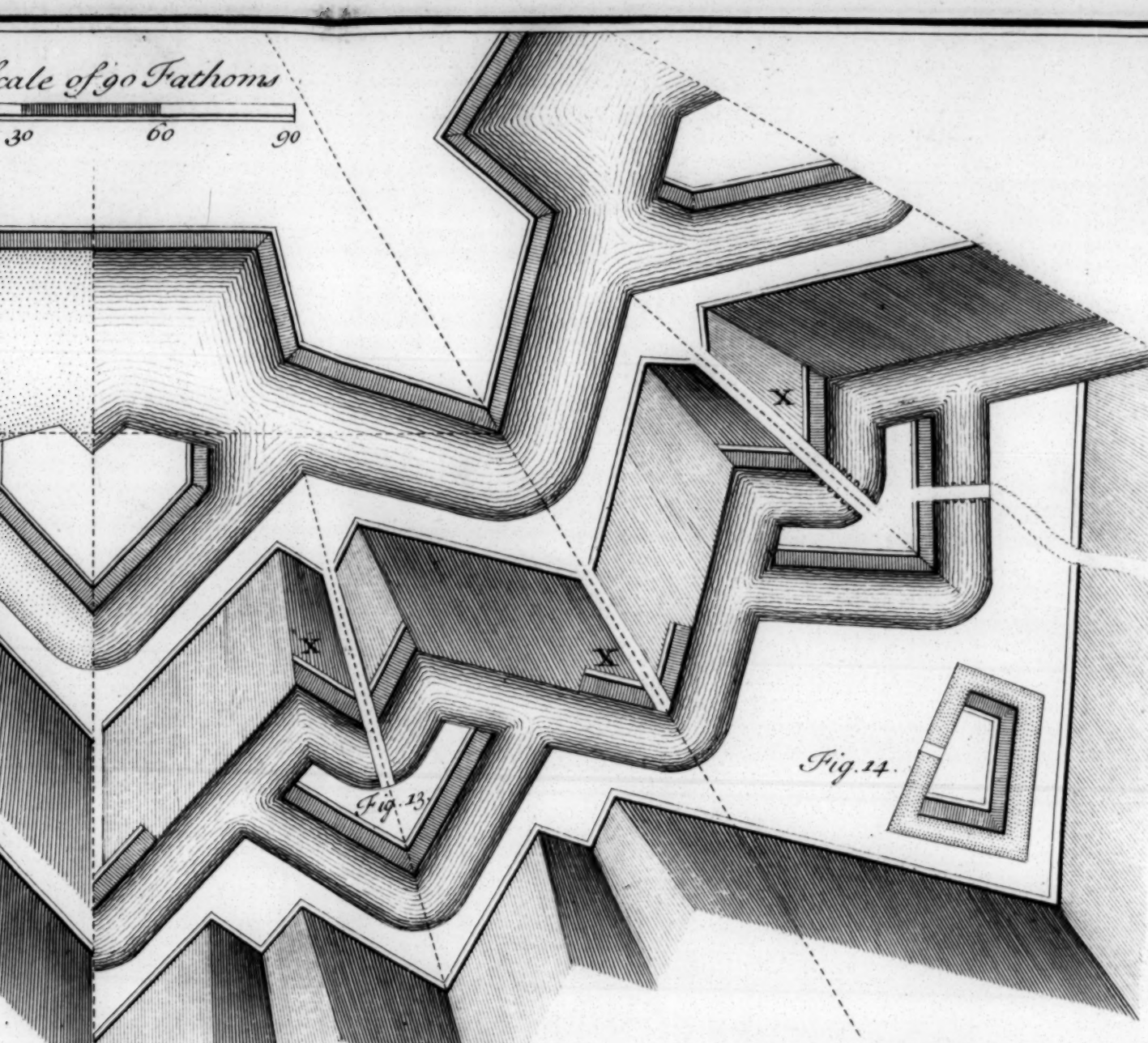
Fig. 9.




A Scale of 90 Fat
10 20 30 60
Fig. 11.



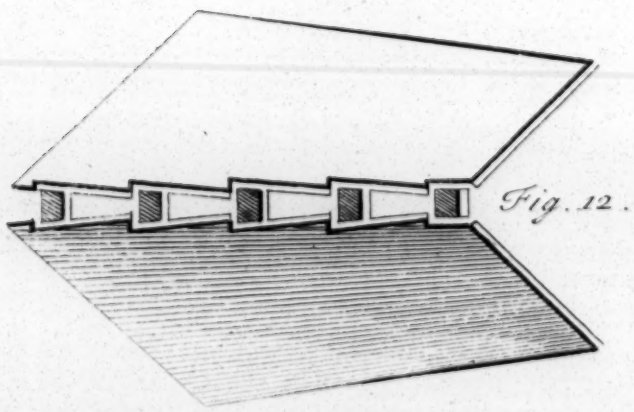
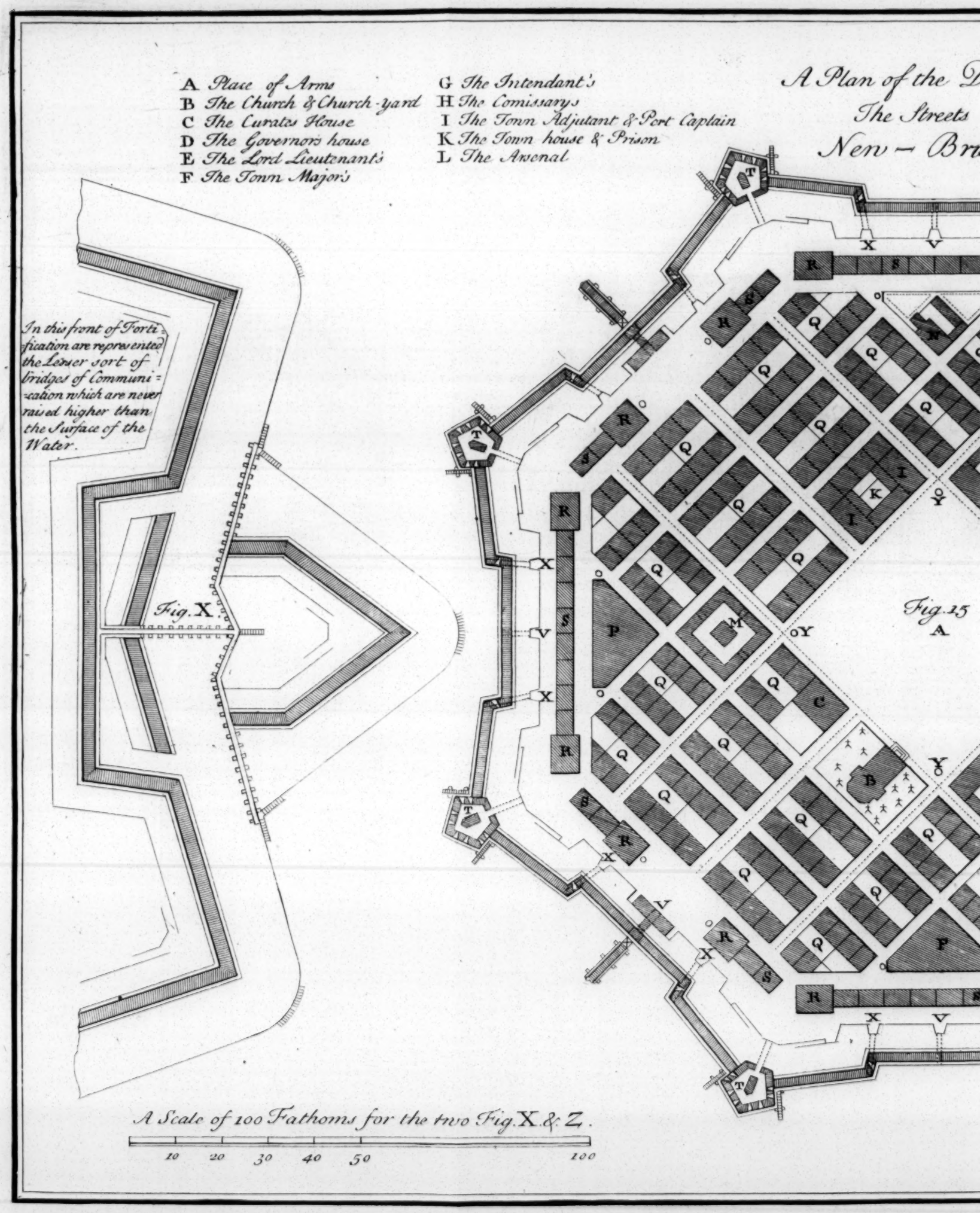


Fig. 12.


A Place of Arms
B The Church & Church-yard
C The Curates House
D The Governors house
E The Lord Lieutenant's
F The Town Major's
G The Intendant's
H The Comissarys
I The Town Adjutant & Port Captain
K The Town house & Prison
L The Arsenal
A Plan of the D
The Streets
New - Bri
In this front of Forti=
=fication are represented
the Lesser sort of
bridges of Communi=
=cation which are never
raised higher than
the Surface of the
Water.
Fig. X.
Fig. 15
A
A Scale of 100 Fathoms for the two Fig. X. & Z.
10 20 30 40 50 100

Plan of the Division of The Streets of New – Brisach

M The Market
N The Convent of Recollet Friars
O The Magazine for Wood
P The Magazine for Stores & Forrage
Q The Burghers' Houses
R The Officers's Pavillions
S The Casems or Barrachs
T The Tower Bastions
V The Gates & Posterns
X Souterreins
Y Wells for Publich use

N.B. The Soldiers Hospital at New-brisach is without the circumference of the Town & is coverd by a large Crown Work

This Plan represents The Caponieres intended as Communication to the Out Works

Fig. 1

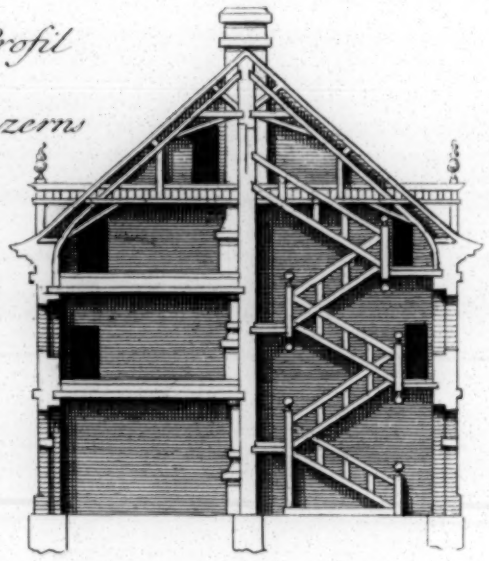
Fig. 2

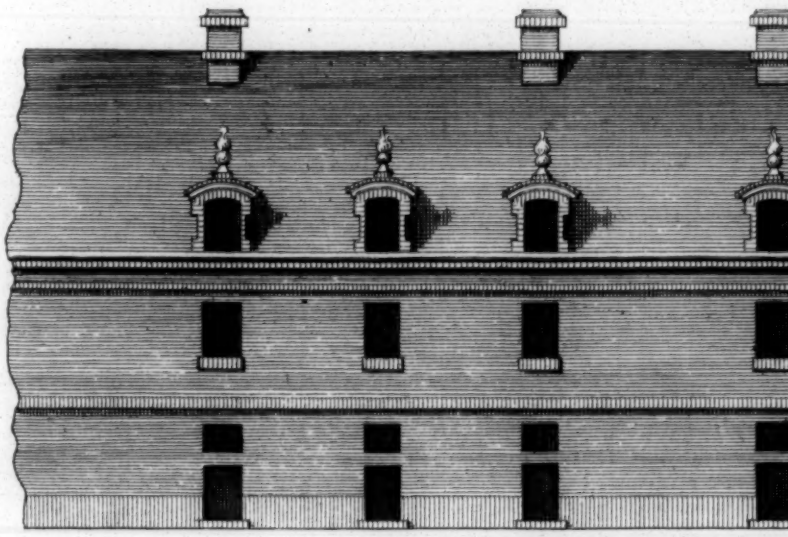
A Scale of 150 Fathoms for the Division of the Streets of New-Brisach.

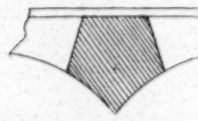
10 20 30 40 50 100 150

The Plan & Elevation of pa

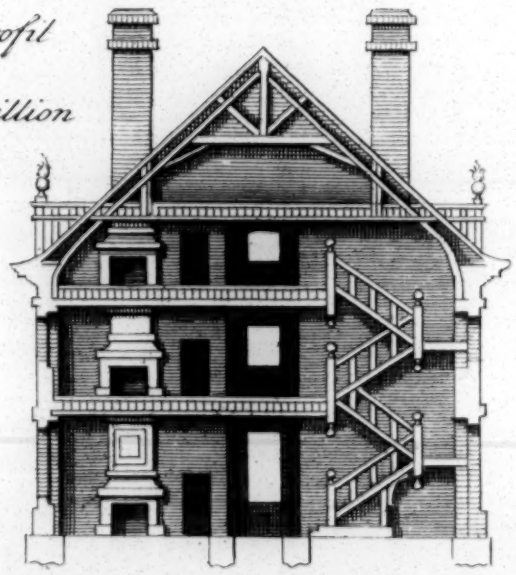
The Profil of the Cazerns

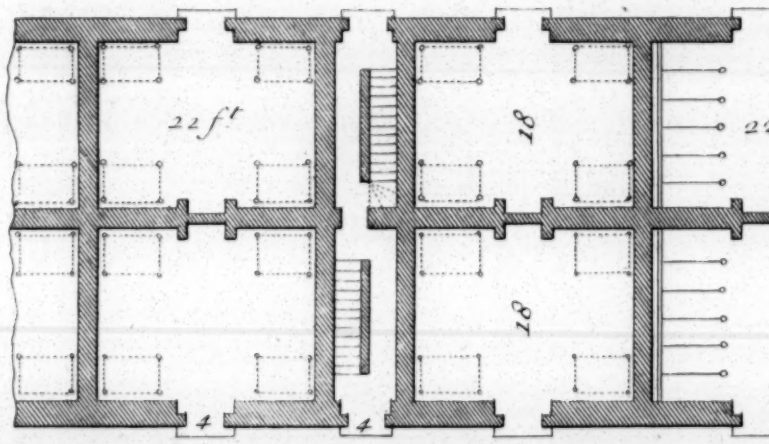






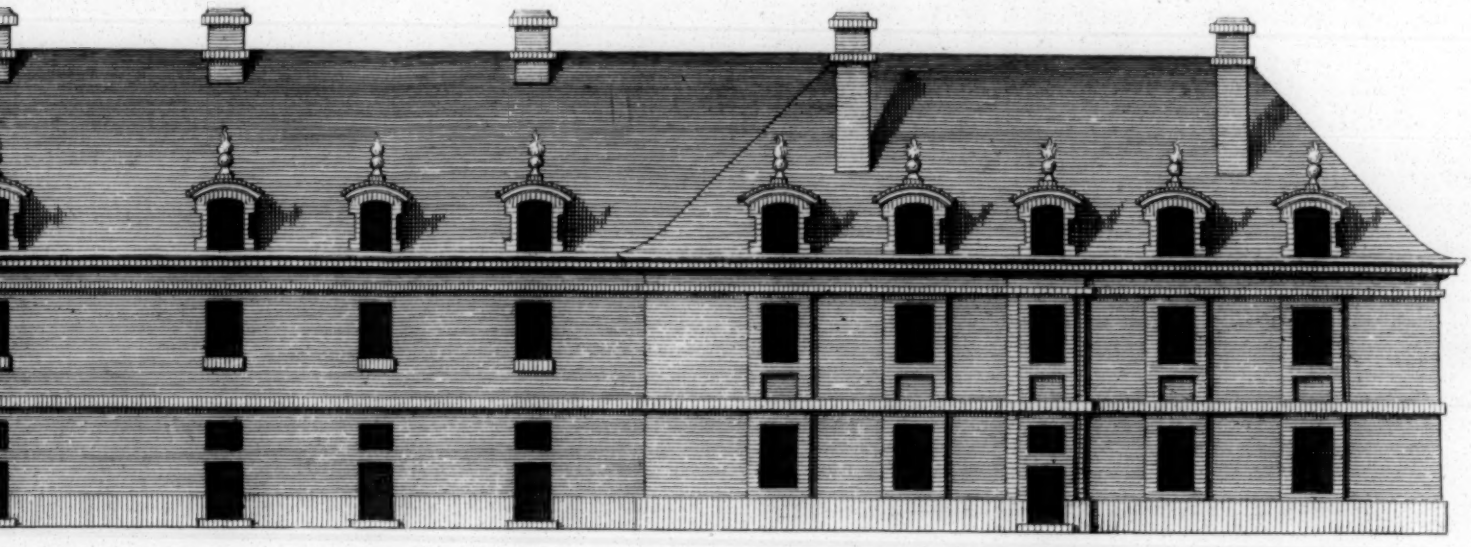
The Profil of the Pavillion

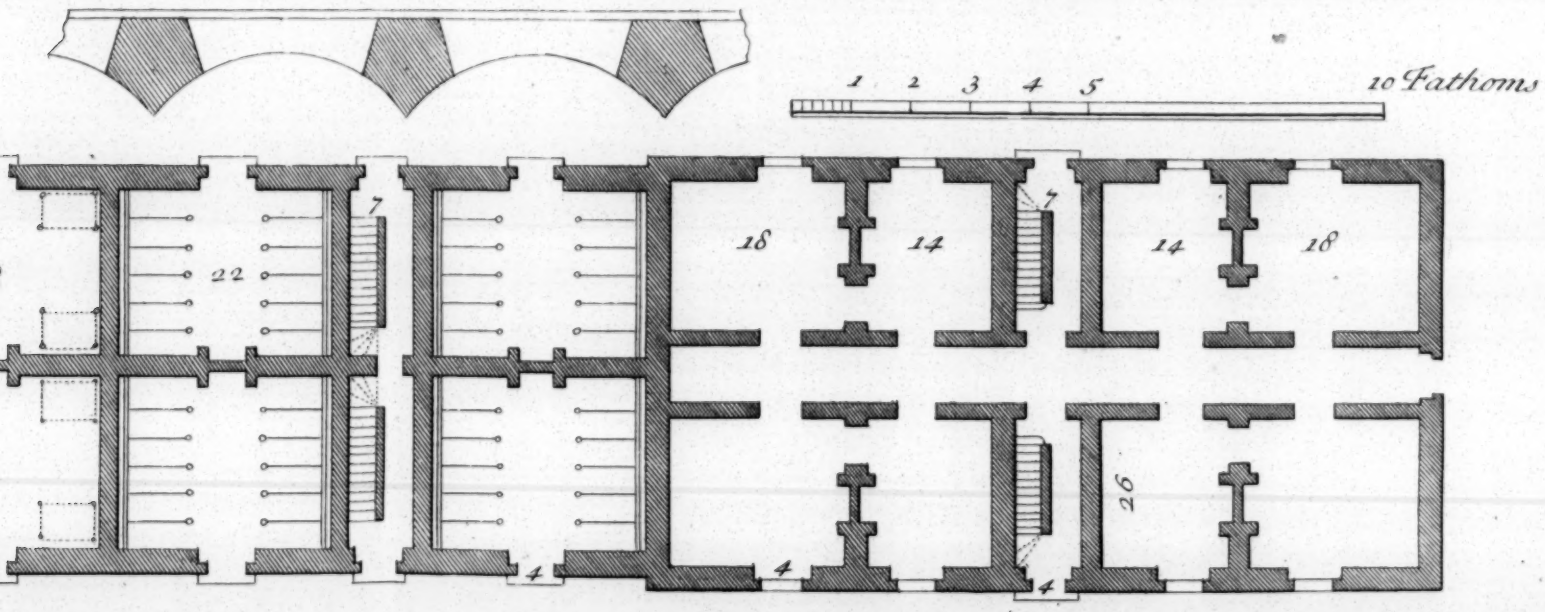




1

levation of part of the Cazerns & of a Pavillion for the Officers

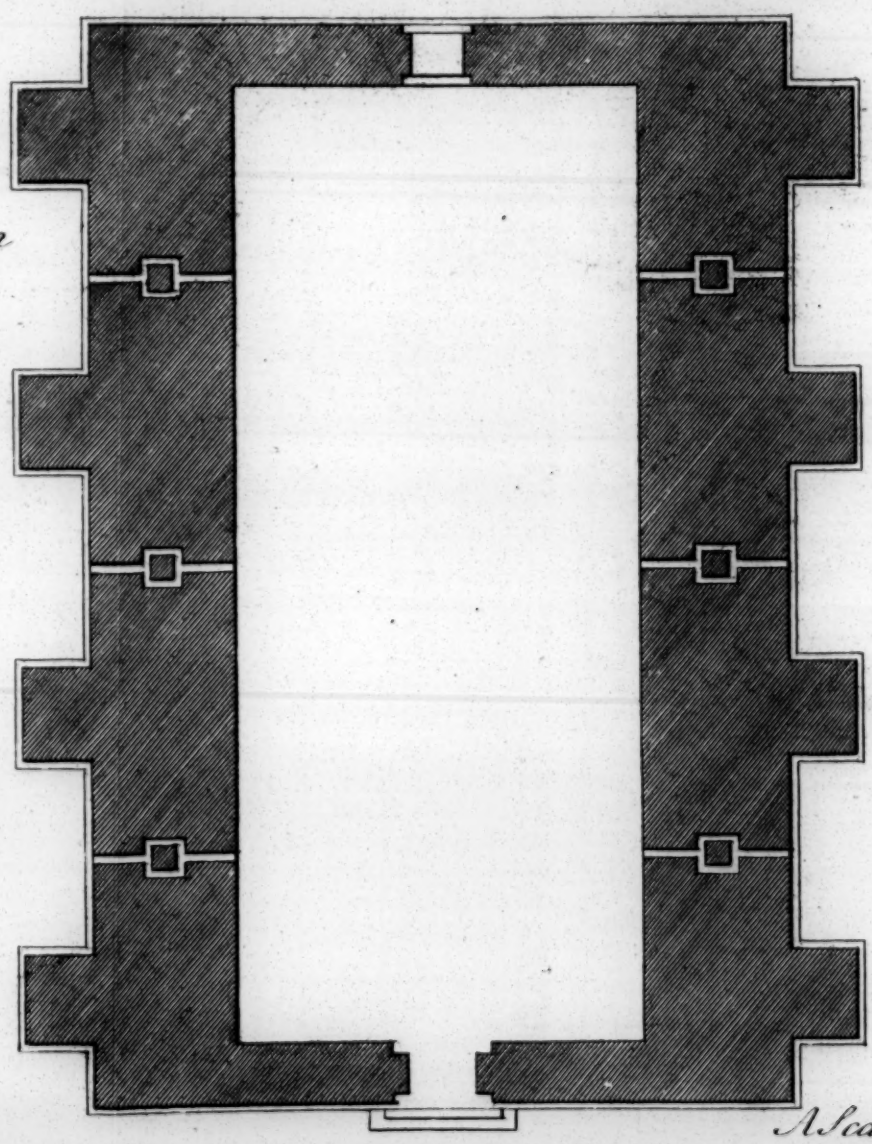




The Surface of the Ground

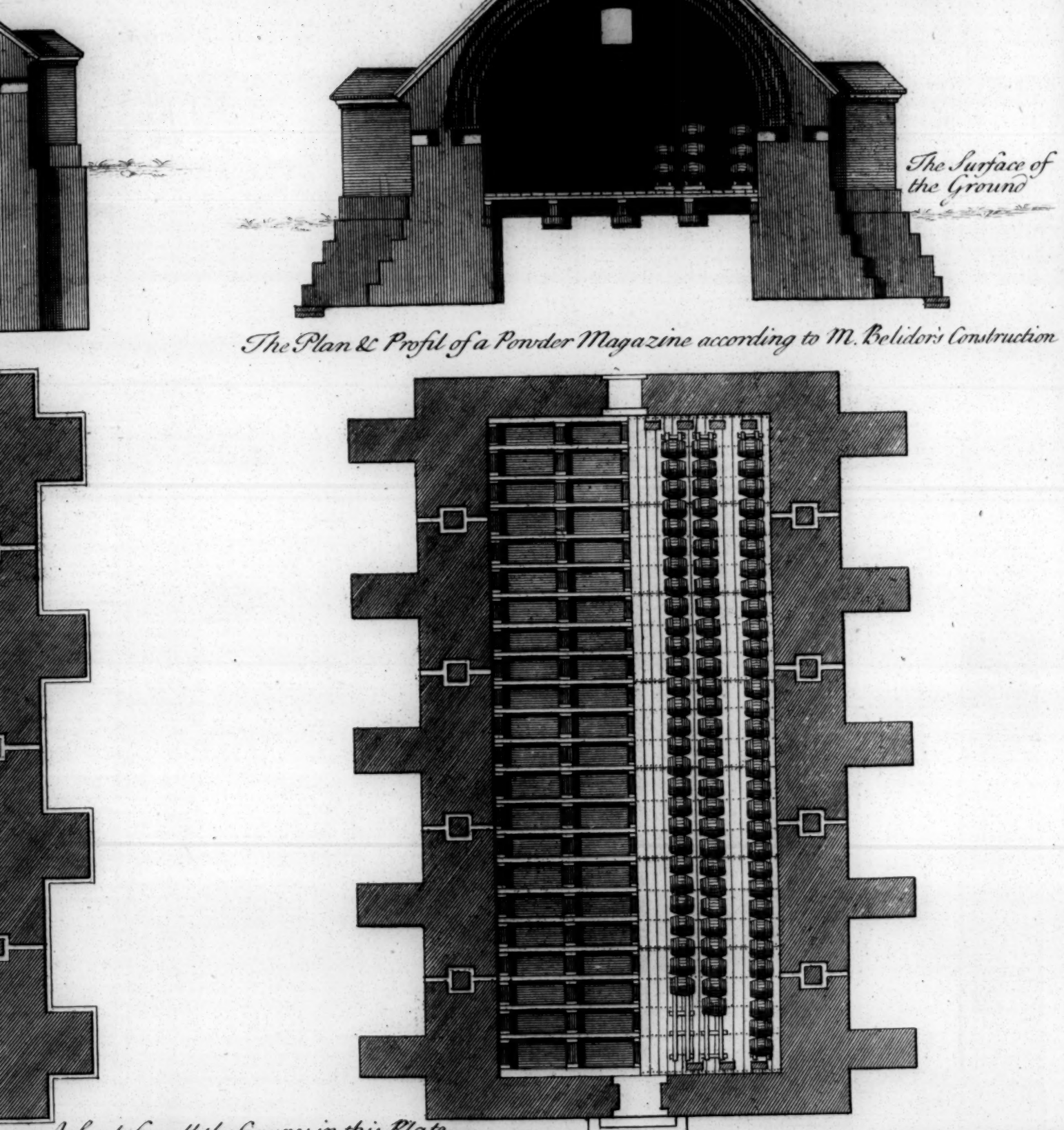
NB The foundations of this Magazine must be supposed to have been intended for a place where it was requisite to make them so massive otherwise they are beyond all proportion.

The Plan and Profil of a Magazine according to M Vauban



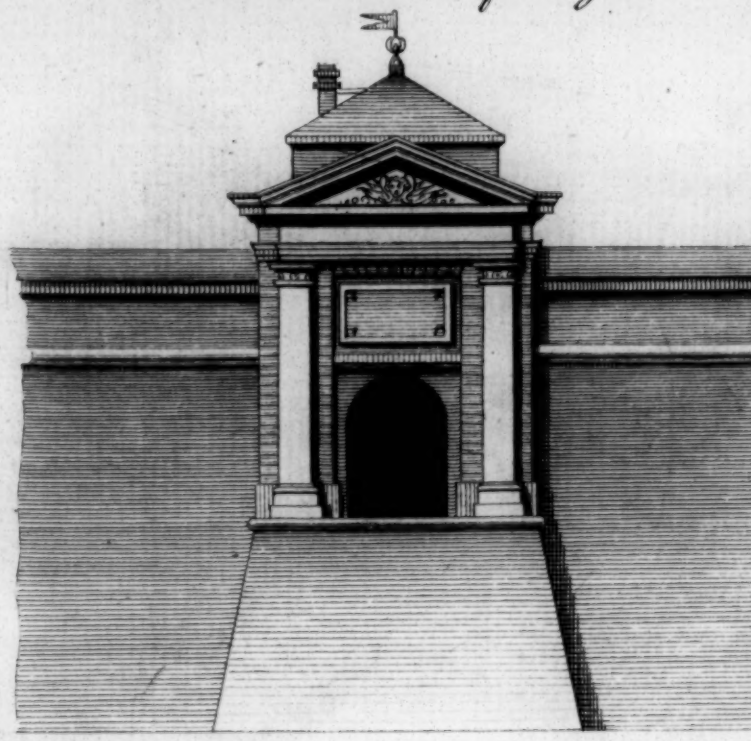
A Scale for o

1 2 3 4

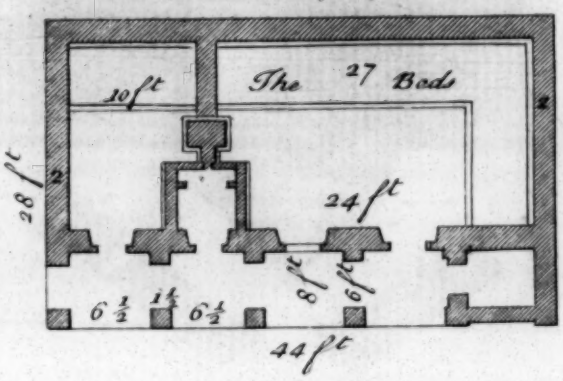


The Plan & Profil of a Powder Magazine according to M. Belidor's Construction

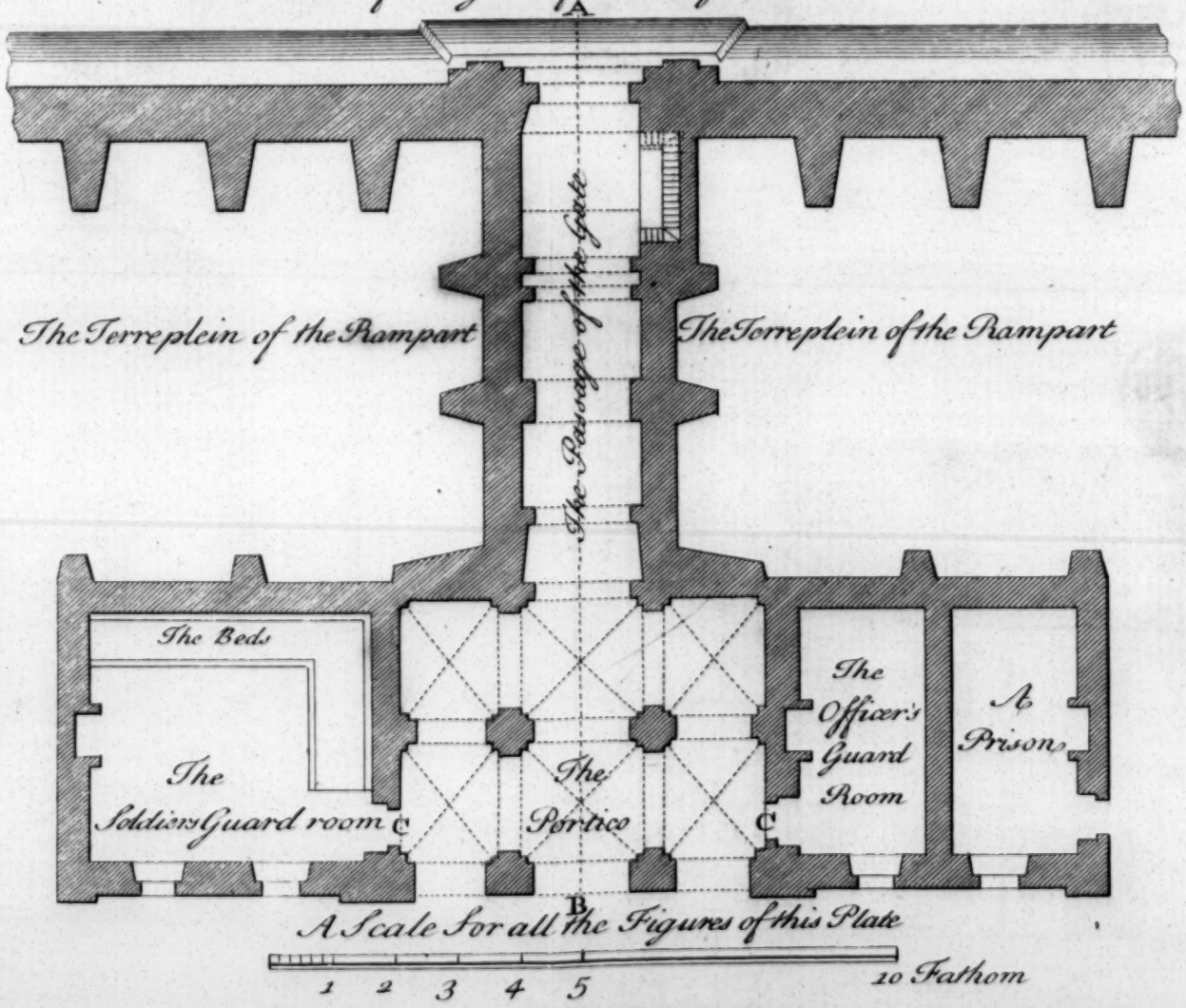
The Exterior Elevation of the Gate



The Plan & Elevation of a Guard-House



The Plan of the Gate of a Fortified Place

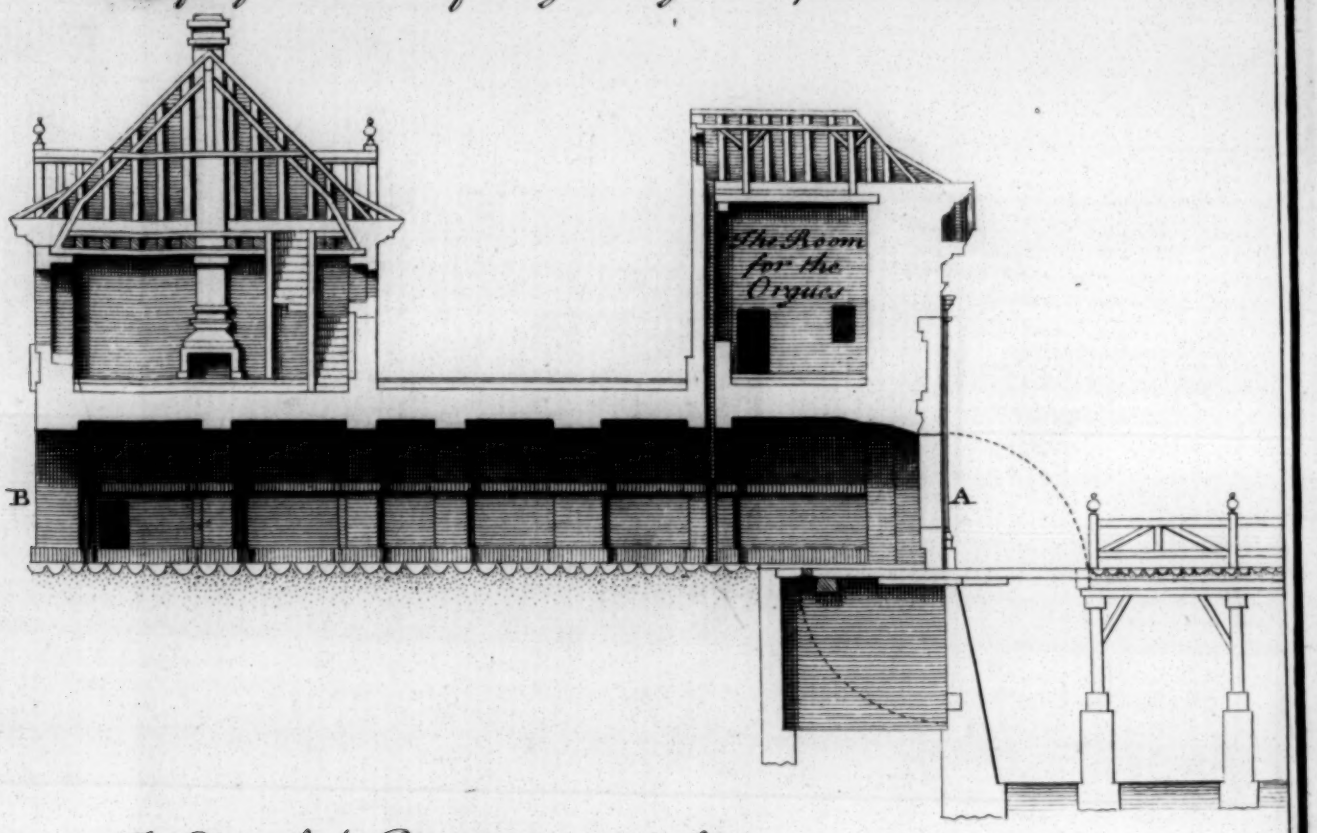


A Scale for all the Figures of this Plate

1 2 3 4 5 10 Fathom

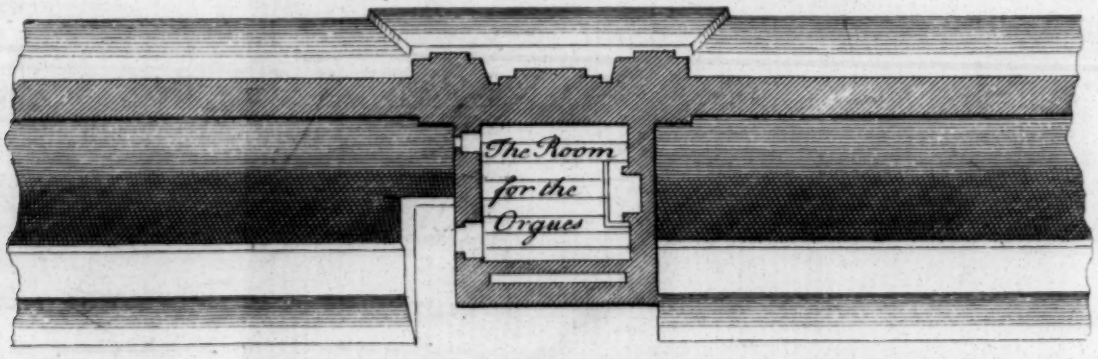
f the Gate

The Profil of the Section of the Gate way taken upon the Line A.B.

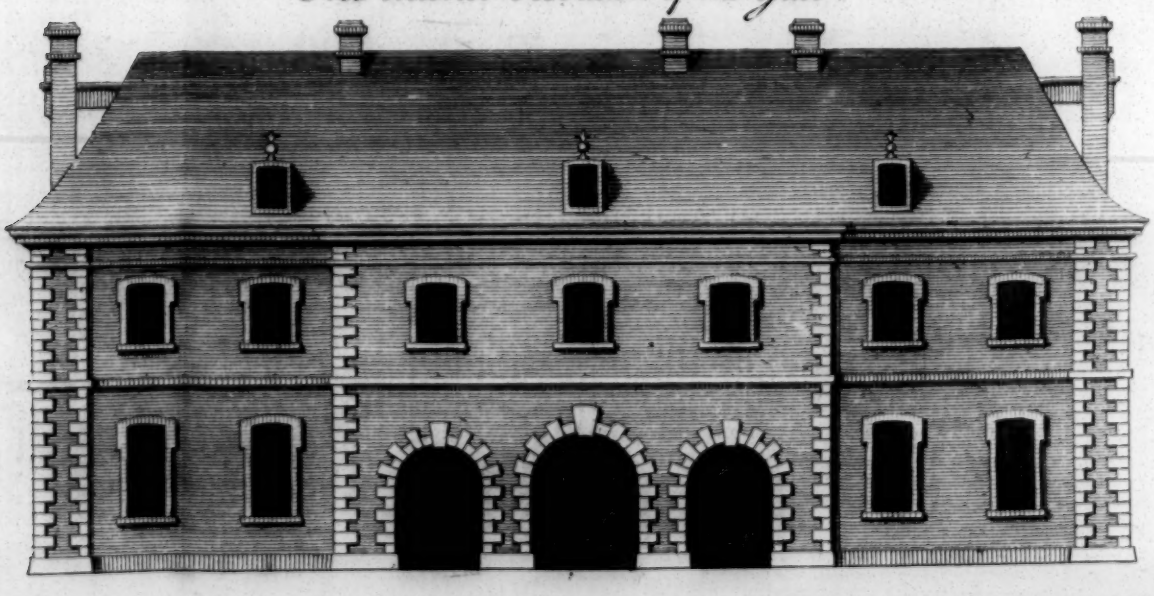


part

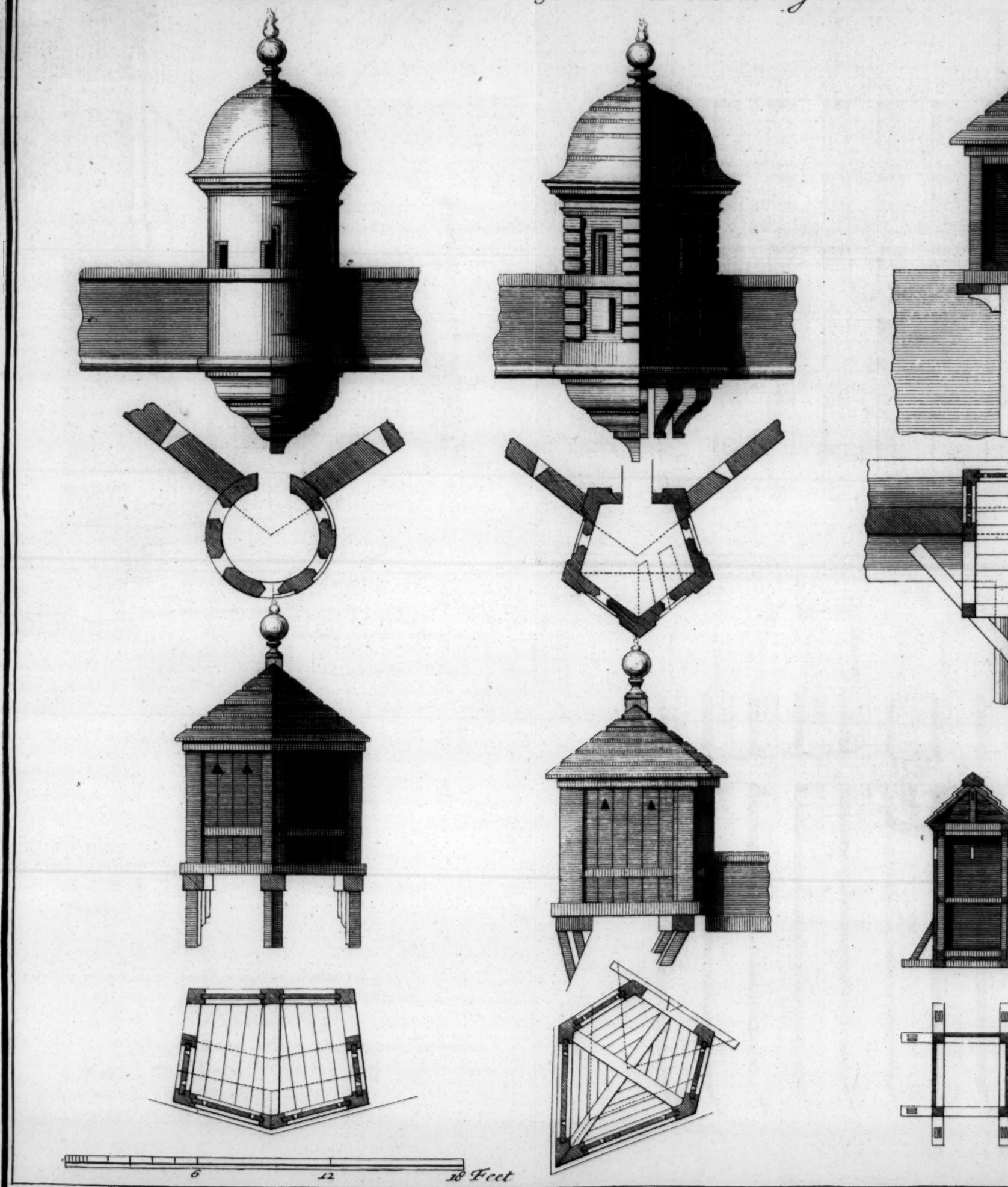
The Plan of the Rampart over the Gate.

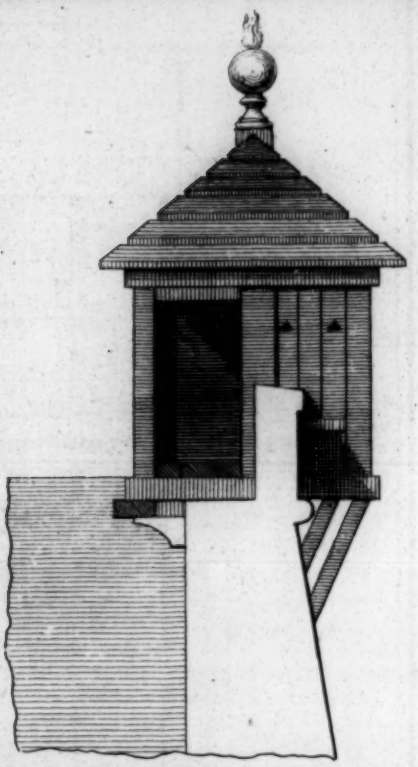


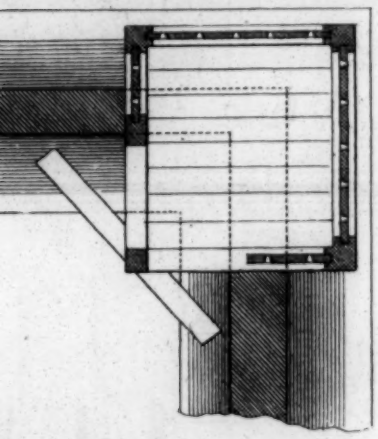
The interior Elevation of the Gate.

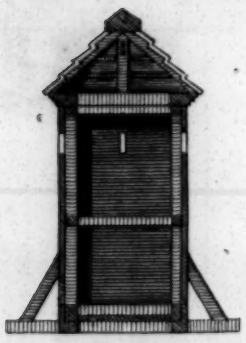


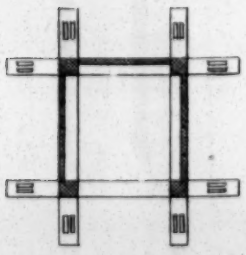
Several Plans & Elevations of Stone & Wooden Guerites

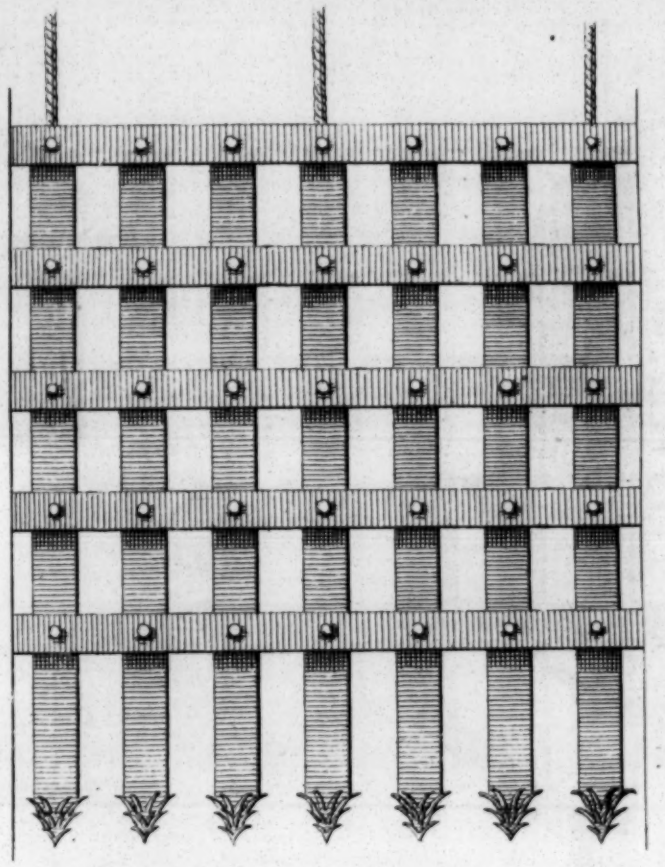












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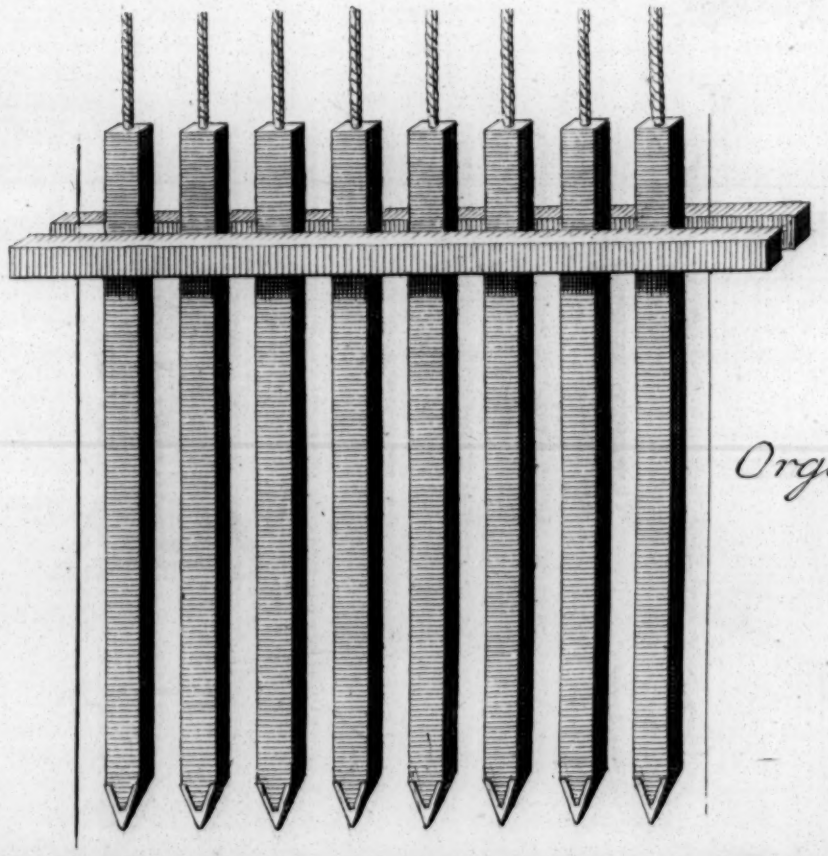


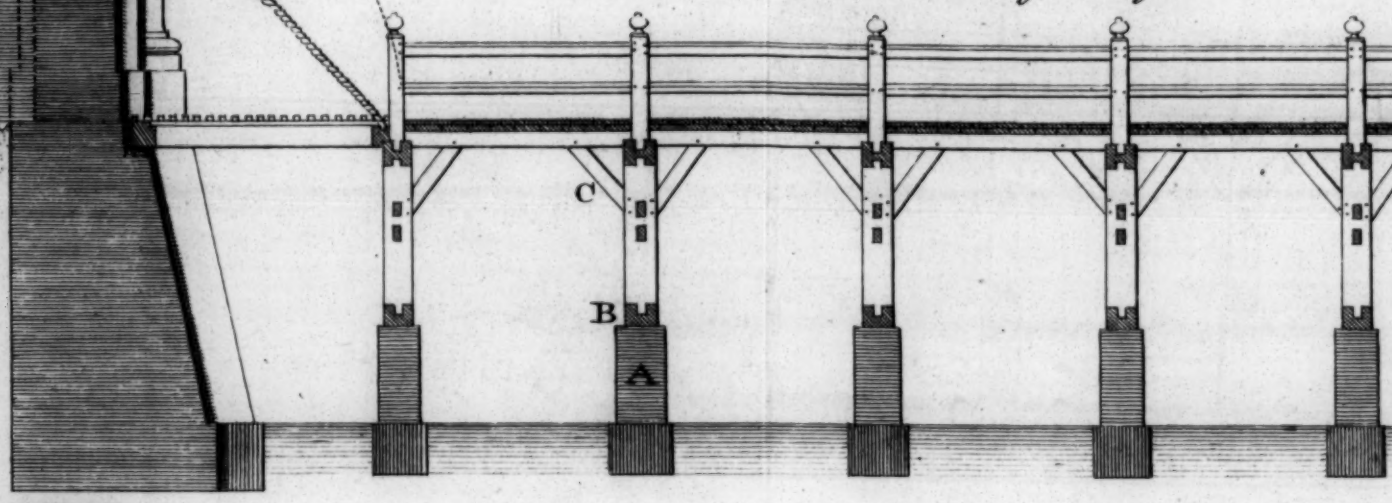
Orgues

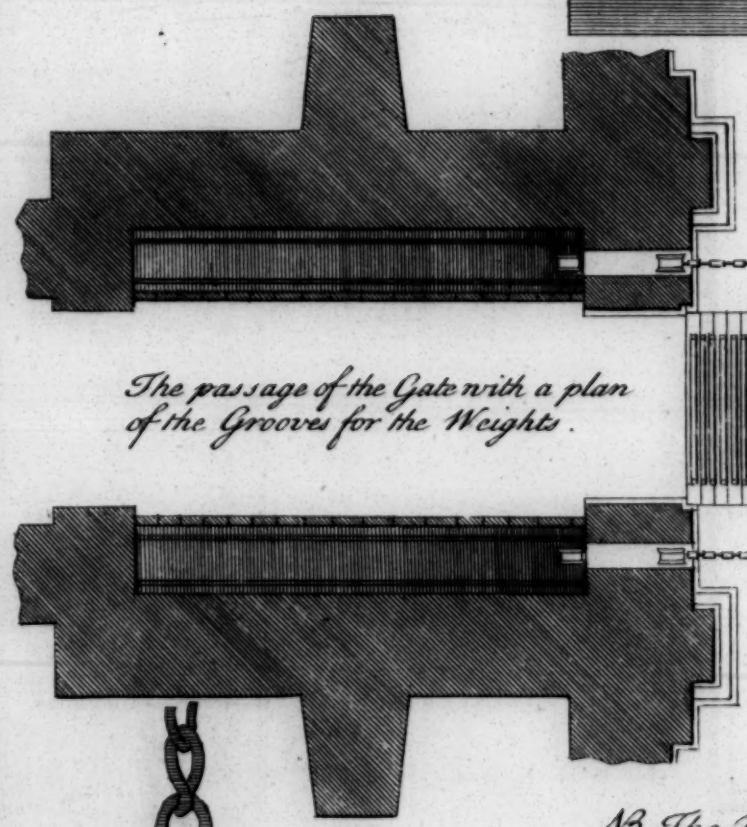
The Profil of the Drawbridges & Standing

A Scale of 10 Fathoms for the Section of the Gate & all the parts of the Gr

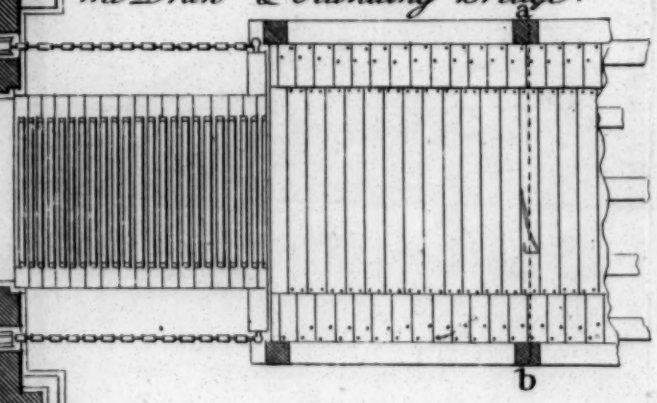
1 2 3 4 5

The Standing Bridge

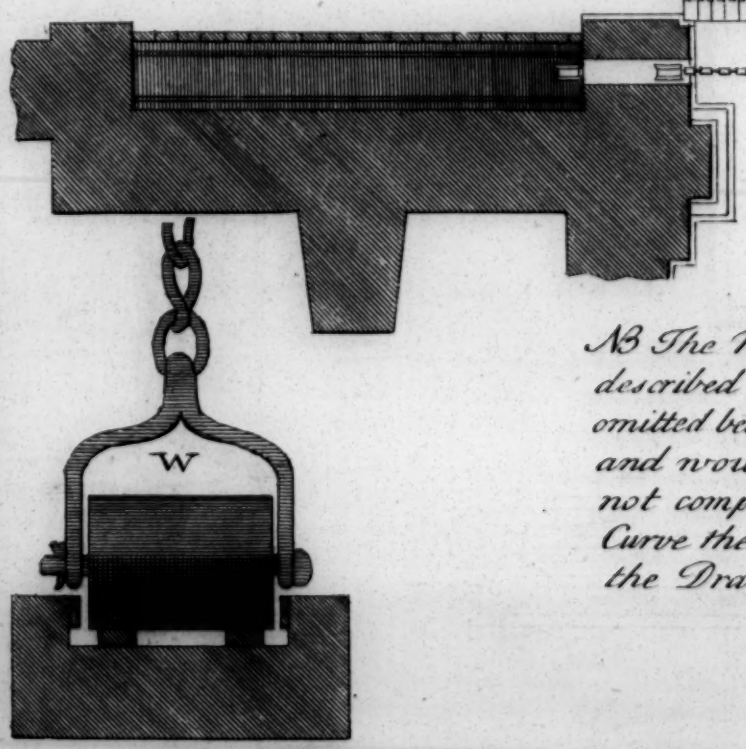




The Plan of
the Draw & Standing Bridge.

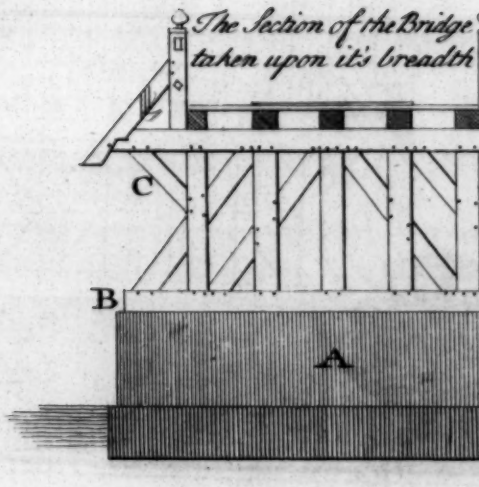


The passage of the Gate with a plan
of the Grooves for the Weights.

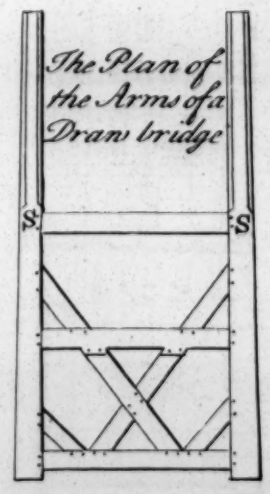


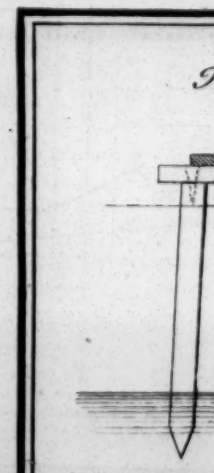
NB The Mathematical Construction of the Curve yy described in the above Section of the Gate is omitted because it is known to Mathematicians and woud Prove needless for those who Coud not comprehend it. by the means of Such a Curve the Weight W is made to Counter-balance the Drawbridge.

The Section of the Bridge
taken upon it's breadth



The Plan of
the Arms of a
Draw bridge





Standing Bridges for the passage over the Great fossè of the Place.

the parts of the Great bridge

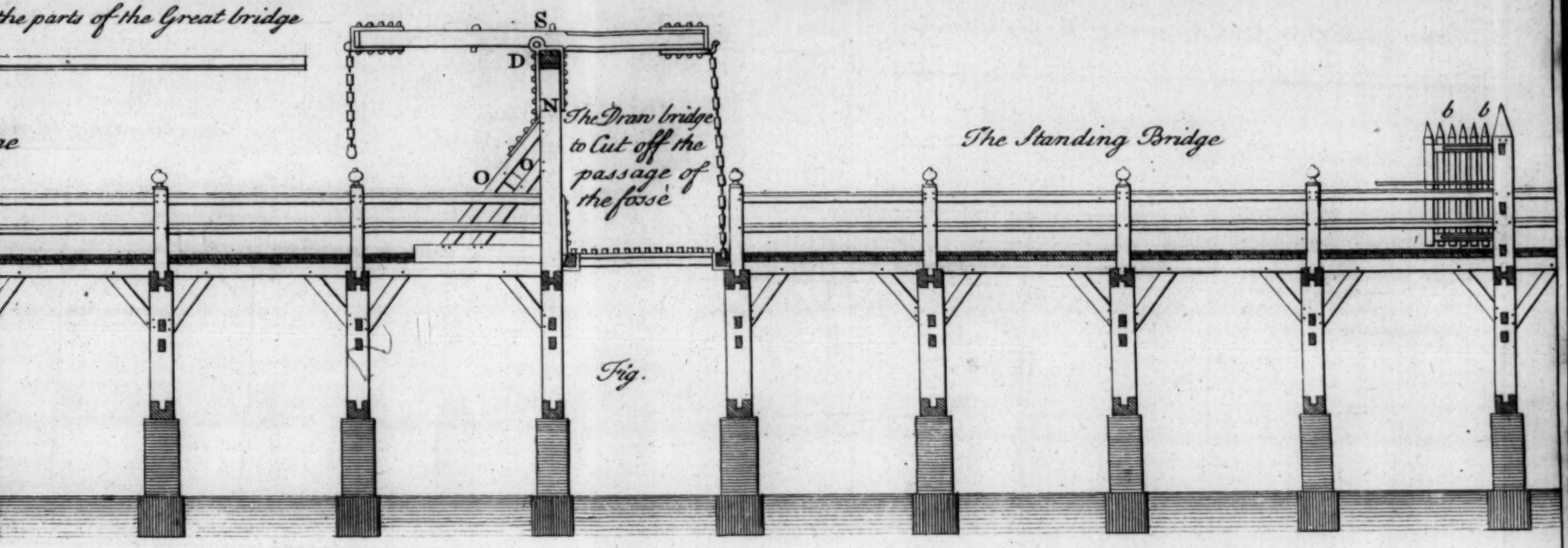
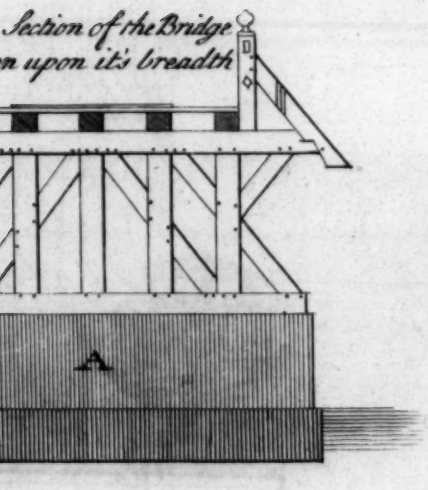
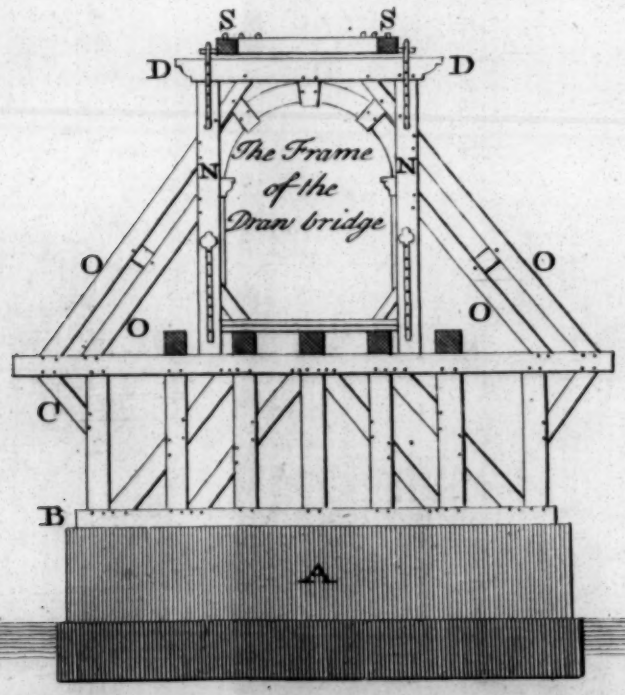


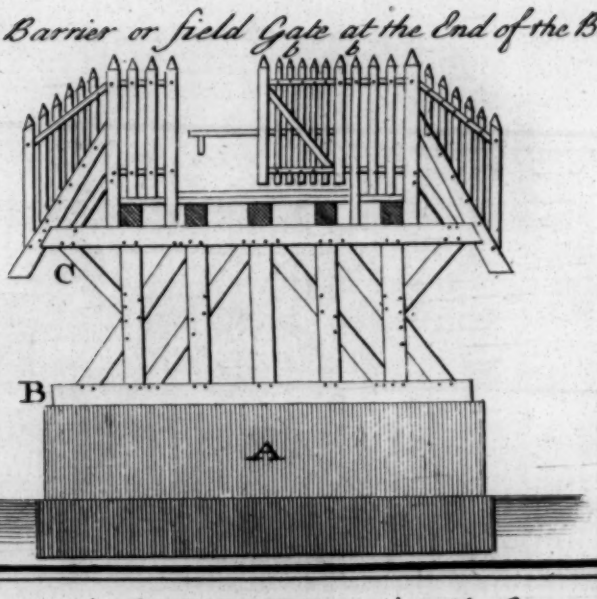
Fig.

Section of the Bridge
n upon it's breadth

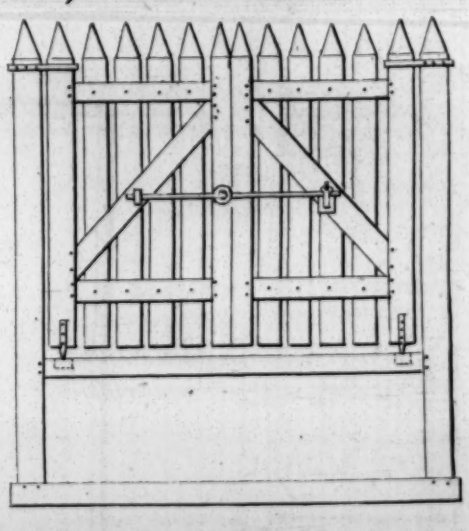




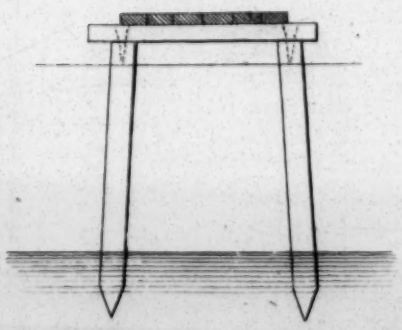
The Barrier or field Gate at the End of the Bridge.



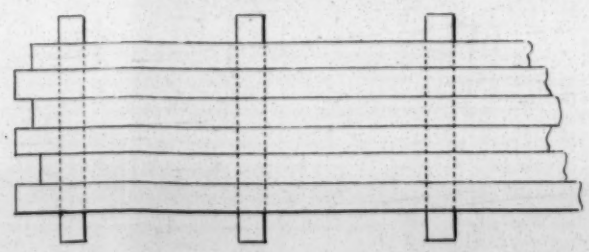
The Barrier for the entrances cut in to the Covert way



The Piles

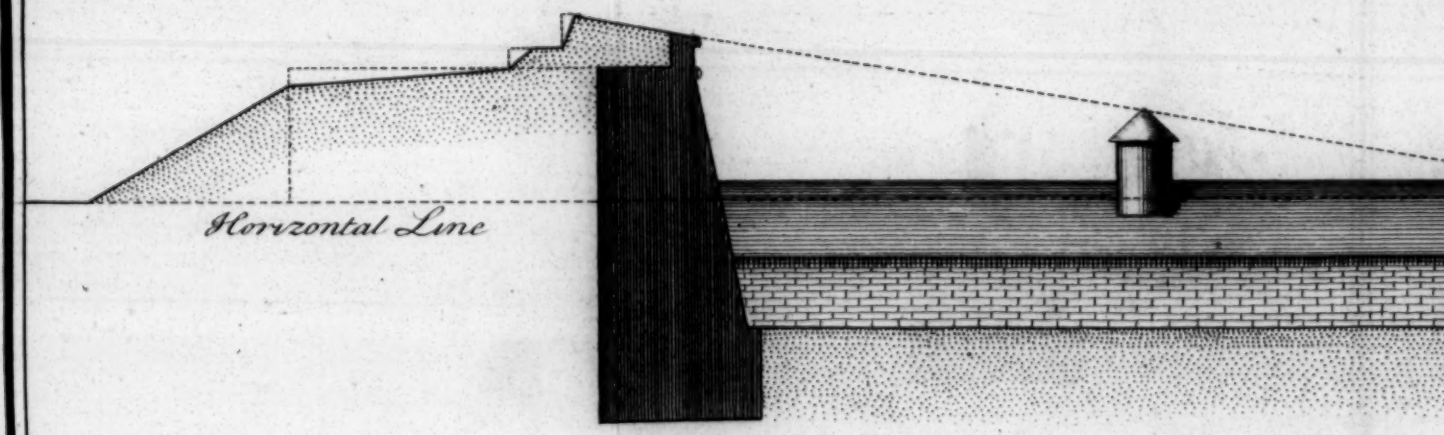


Little bridge of comunication



The Elevation of a Batardeau described the Whole bre

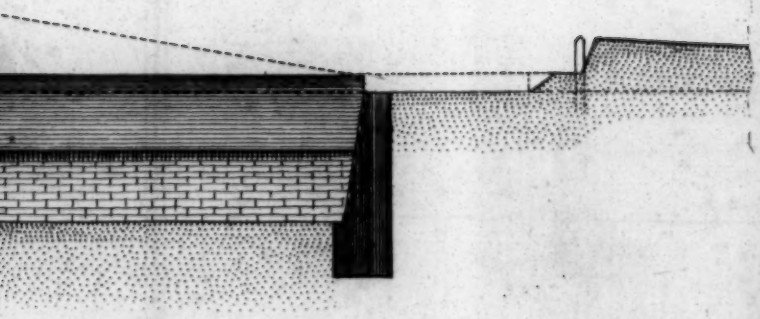
upon the face or Capital of a Bastion prolonge



A Scale for the Elevation & Profil

1 2 3 4 5 10 Fat

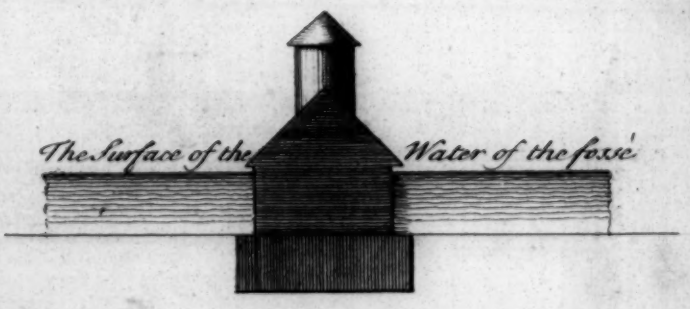
he Whole breadth of the fosse
ion prolonged

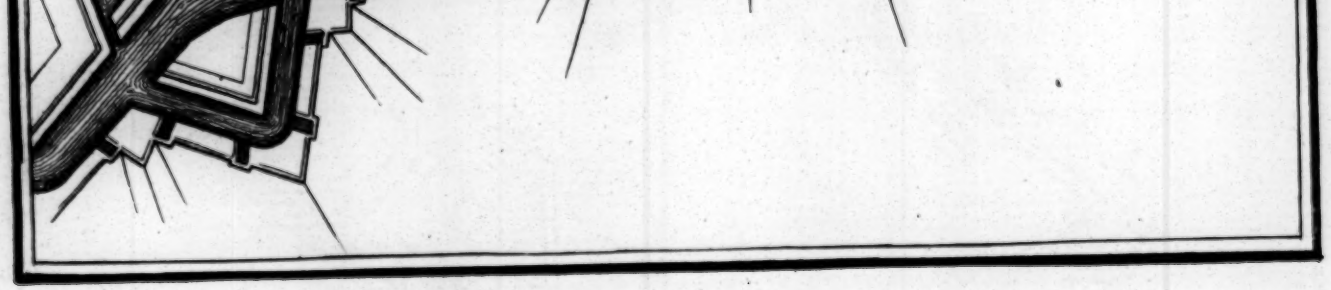


tion & Profil

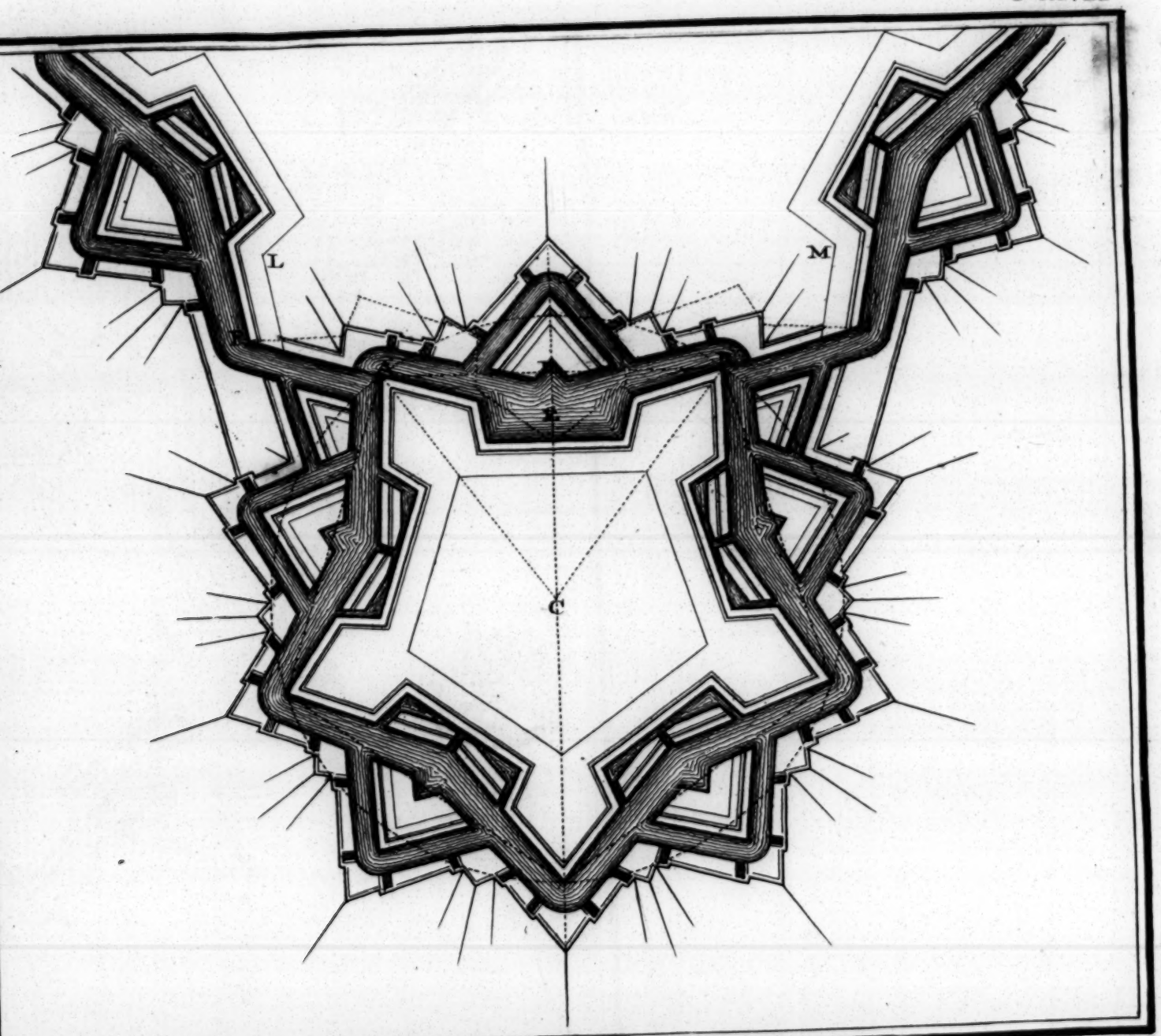
10 Fathoms

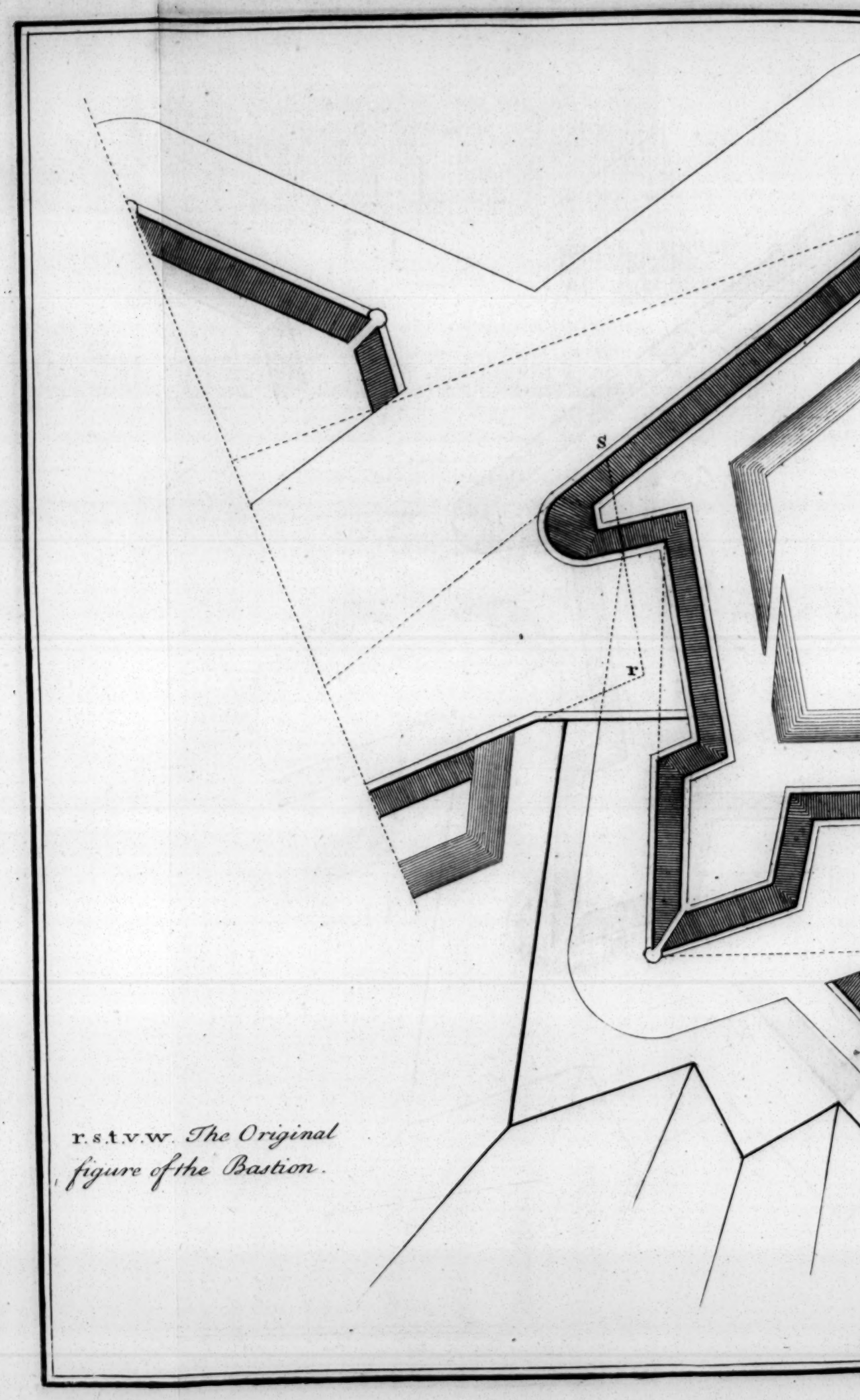
The Profil of the Section
of
a Batardeau
taken upon it's breadth



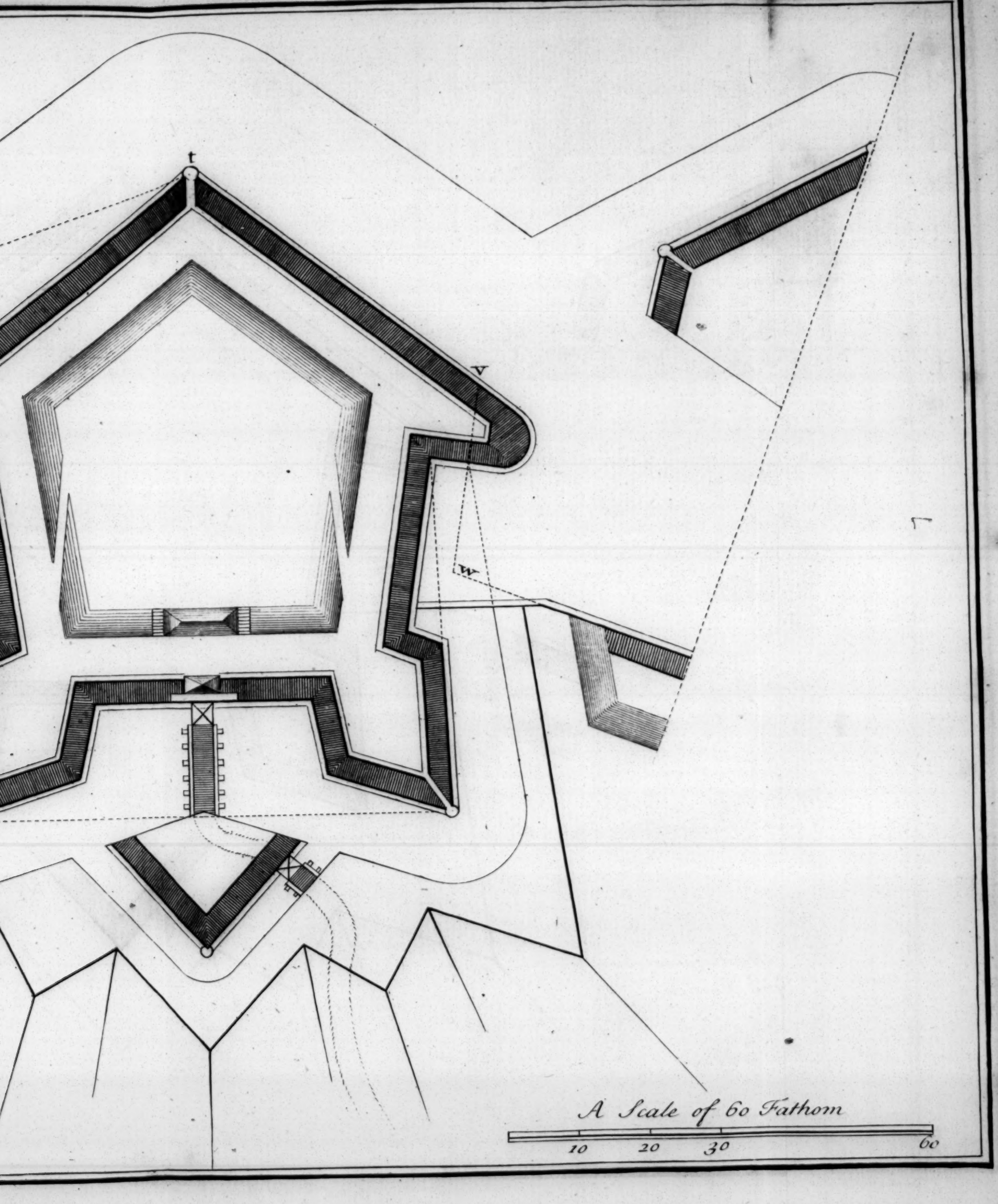


Pla. 21





r.s.t.v.w. *The Original figure of the Bastion.*


t
V
W
A Scale of 60 Fathom
10
20
30
60

Profil taken upon the length of the Postern fig. 3.

Fig. 1.

Profil taken upon the length of the Souterreins

Fig. 5.

Cavalier

Fig. 6.

Cavalier

Rampart

Profil taken upon the breadth of the Souterreins

A Scale for fig. 5. 6. & 7.

5 10 20 30 Fathoms

A Sc

1 2

Fig. 7.

Chimny

Chimny

Chimny

Chimny

Chimny

Cistern

Ovens

Ovens

Cistern

Souterreins

Souterreins

Souterreins

Souterreins

Cistern

Ovens

Ovens

Cistern

A Plan of the Souterreins as practised in a full Bastion

Entrances into the Souterreins

Profil taken upon the breadth of the postern fig. 3.

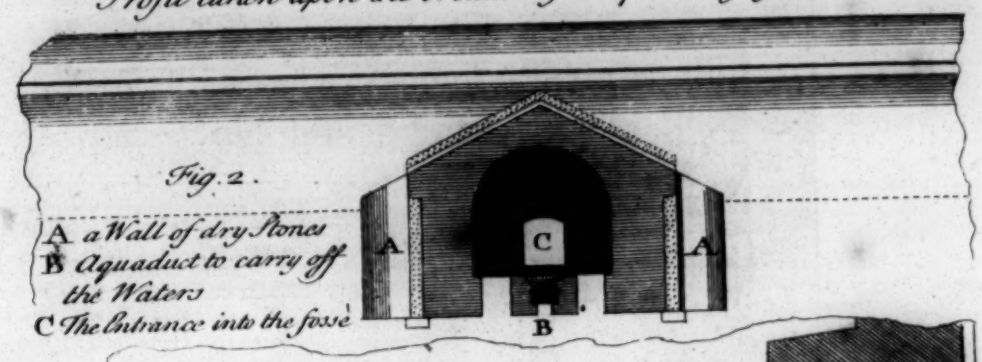


Fig. 2.

A a Wall of dry Stones
B Aquaduct to carry off the Waters
C The Entrance into the fossé

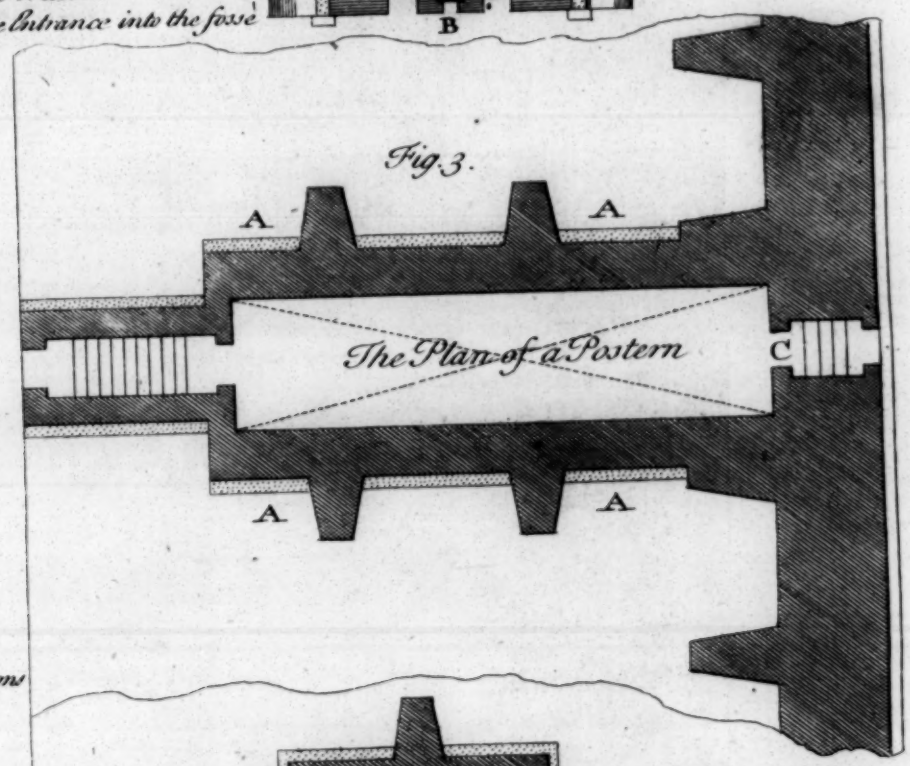
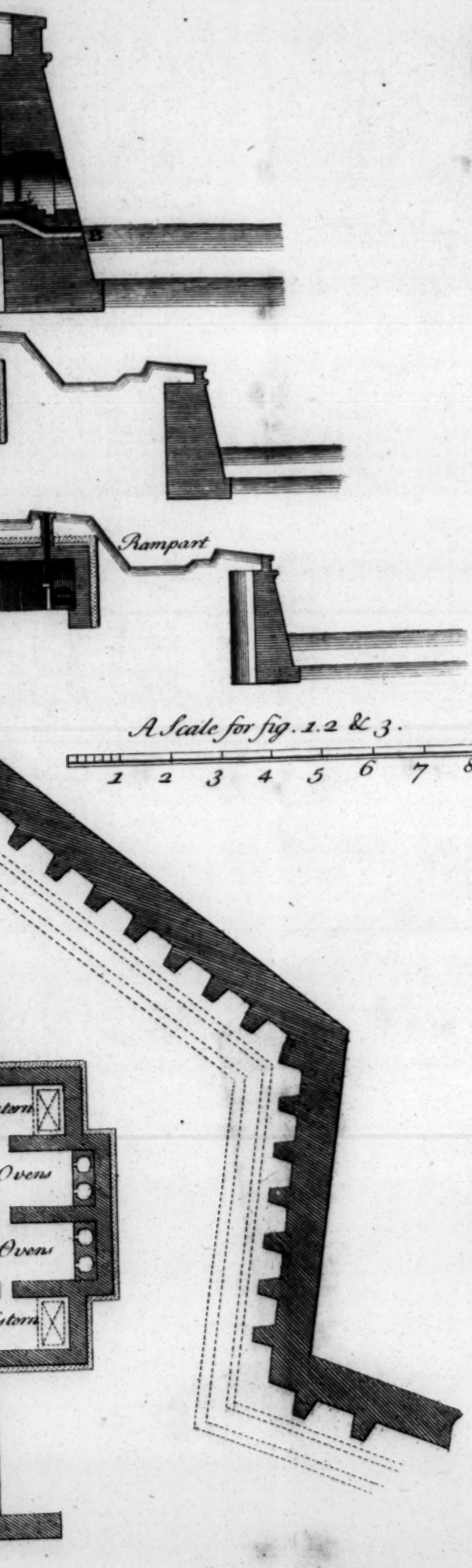


Fig. 3.



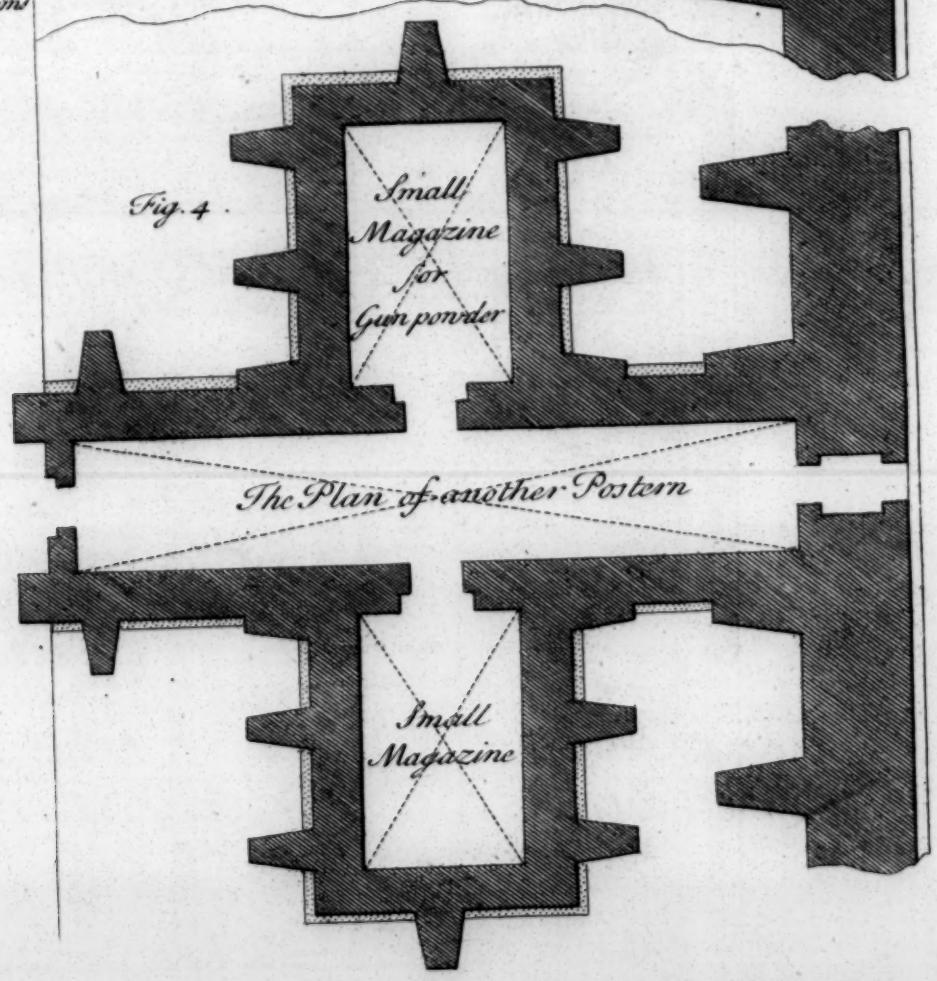


Fig. 4.

that is bomb-proof, and ſerves for a retreat when the town is beſieged. PLATE 23.

Souterrains are of great advantage in ſmall fortreſſes, citadels, caſtles, &c. where the enemy's inceſſant fire ſets the whole place of a blaze; whereas in great towns there is always ſome part or other the moſt diſtant from the attacks, that eſcapes the fiery ſhowers of the enemy's batteries, and is therefore a convenient and ſafe quarter for all the warlike ſtores, proviſions, &c. and for the ſick and wounded.

The plans of the profils deſcribed in the Plate above-mentioned are ſufficient to give a true idea of the conſtruction of theſe ſubterranean works. In the building of any of them, the greateſt care muſt be taken that no water or damps can ever damage them; for this reaſon the wall of dry ſtones two feet thick, laid by hand without mortar, only with gravel, is made to cover every part of the other walls above and on their ſides, as may be ſeen by the dotted parts marked A A in the plans and profils. For a further precaution, drains are made to carry off the water, and ſeveral chimneys contrived to air theſe Vaults, and for the fire-places uſed in theſe habitations under ground.

CHAPTER III.

THE SECOND AND THIRD SYSTEMS OF M. DE VAUBAN.

The ſtructure of the ſecond ſyſtem.

M. *De Vauban* has only practiſed this ſecond ſyſtem at *Beſſort* and *Landaw*. The diſadvantageous ſituation of *Beſſort*, and the impoſſibility there was to fortify this place with common baſtions, without being expoſed to *enfilades* almoſt on every ſide, notwithſtanding the traverſes and other elevations that could have been raiſed againſt them, obliged this great engineer to invent a ſmall ſort of baſtions, in which are made vaults that are bomb-proof; theſe baſtions are called *tower-baſtions*, and they are covered by counter-guards, the top of whoſe parapets is almoſt as high as the parapets of the towers.

Altho' the two places abovementioned are both of them irregular, the one in its angles, and the other in its angles and its ſides, yet we can apply this ſyſtem to regular fortification, as will appear by the following ſtructure. PLATE 24.

Let A B repreſent the ſide of a regular hexagon, and its length be ſuppoſed 120 fathoms. Take A M and B K four fathoms each; from the points M and K raiſe the two perpendiculars M N, K F, of ſix fathoms; let fall from the point N, upon the radius A G prolonged, the perpendicular N T; make T G equal to T N, and join N G by a right line; in the ſame manner draw the line F L, thus you will deſcribe the ſmall half-baſtions G N M, K F L, whoſe demigorges are A M and K B; the flancs are N M and

and FK, and the faces NG, FL. Theſe ſmall baſtions are what we have ſaid to be tower-baſtions. This done, through the angle of the ſhoulder N, and through the flanked angle L of the oppoſite tower, draw the line NL; in the ſame manner join FG. Upon the interior ſide AB take AC and BD, each equal to the fourth part of AB, *viz.* 30 fathoms; upon the two points C and D raiſe the two indefinite perpendiculars CQ and DP; afterwards prolong outwards the two capitals BL and AG, and make LR and GI 39 fathoms each; then draw the two lines MR and KI; theſe lines will interſect the perpendiculars CQ and DP at the points P and Q. Take DV and CS of one fathom each, and join by right lines PV and QS, which are determined at Z and H by the interſection of the lines NL and FG. Thus are deſcribed the two half *detached-baſtions* or counter-guards IQH, RPZ, whoſe faces are IQ and PR, and the flanks are QH and PZ.

To trace the foſsè of the tower-baſtions; upon the line HG ſet off from the point H, HO of ten fathoms; from the flanked angle G, as center, with an interval of ſeven fathoms, deſcribe an arch, to which draw a tangent from the point O, thus you will have traced the foſsè of the tower-baſtion A; repeat this conſtruction for the foſsès of the tower-baſtion B, and of all the others of the polygon.

Theſe foſsès might be traced by drawing a parallel to the face of the tower GN, *at ſeven fathoms diſtance, the parallel being prolonged till it interſects the line* GH *in a point, as at* O.

It is proper to make uſe of this laſt conſtruction to trace the foſsè of the tower, whenever the polygon contains fewer ſides than an hexagon, that it may have the ſame breadth at the angle of the ſhoulder as at the flanked angle; but for an

hexagon, and all ſuperior polygons, the ſtructure at firſt given will ſerve.

The foſsè of the counter-guards is traced as that of the body of the place laid down in the firſt chapter, to which we refer the reader, only deſcribing the arch at the flanked angles, with a radius of fifteen fathoms.

Before the curtin are raiſed tenails, in the ſame manner as thoſe of the firſt ſyſtem of our author; the interior ſide of theſe tenails are taken upon the line HZ.

For the ſtructure of the half-moon before the tenail, give to its capital 45 or 50 fathoms. The faces thereof muſt be drawn upon the faces of the counter-guards at 10 fathoms diſtant from their angles of the ſhoulders; within the half-moon is made a reduit, whoſe capital is allowed 15 or 20 fathoms, and whoſe faces are drawn parallel to thoſe of the half-moon. The breadth of the foſsè of the half-moon is 12 fathoms, and that of the reduit is five or ſix fathoms.

The conſtruction of the covert-way and glacis in this ſecond ſyſtem has nothing peculiar.

The terre-plein of the rampart of the body of the place, and of the counter-guards, is ſix fathoms broad, that of the half-moon four fathoms, and that of the reduit three fathoms. All the parapets are three fathoms broad, excepting that of the tower-baſtions, which are of ſolid maſonry, and only one and a half fathom thick. What is to be remarked in the conſtruction of this ſyſtem is,

1. That the flanked angles of the tower-baſtions are right angles in all polygons, excepting the ſquare, wherein it is formed by the interſection of two arches deſcribed from the angles of the ſhoulder, taken as center, with a radius of twelve fathoms.

2. The

2. The line drawn from F to G ſhews evidently, that the cannon or muſquet fired from the point F can defend the flanked angle G of the tower G N M, conſequently the whole flanc F K is uſeful to defend the face of the oppoſite tower.

3. The tower-baſtions are covered and hidden from the enemy's view by the counter-guards or detached baſtions raiſed before them.

4. There is made beneath the platform of each tower a ſouterrain that is bomb-proof; within this ſouterrain, at each flanc, are made two cazematted embrazures, which are almoſt level with the ſurface of the water of the foſsè. The cannon placed in theſe parts are ſecure from being diſmounted by the enemy's cannon or bombs; this ſtructure gives an upper and lower flanc.

The terre-plein of the towers is 18 feet above the horizontal line; the rampart of the counter-guards is four feet lower.

We have not given the profils of this ſyſtem, as thoſe deſcribed for the following will ſerve to clear every difficulty that may ariſe from this omiſſion.

The conſtruction of the third ſyſtem of M. de Vauban.

THIS ſyſtem is little different from the foregoing, and what amendments and improvements there are made were effected in the fortifying of *New-Briſach*.

For the conſtruction of this ſyſtem, let A B be one ſide of an octogon, containing 180 fathoms in any polygon whatſoever. PLATE 25.

Having divided A B into two equal parts from the point of the diviſion, let fall within the polygon the perpendicular C D of 30 fathoms; from the points A and B, through the

the point D, draw the lines of defence A D M, B D L, indefinite. Take A E and B F 60 fathoms each for the faces of the counter-guards; then fixing one leg of the compaſſes at F for the center, extend the other to fall upon the point E, and with the interval F E interſect the line of defence B L with an arch; upon which ſet off E to G 22 fathoms; afterwards join E G by a right line for the flanc of the counter-guard. In the ſame manner, fixing the leg of the compaſſes at E, with the ſame intervals, deſcribe F H for the oppoſite flanc; draw from H to G, the interior extremities of theſe flancs, a right line prolonged on both ſides, to interſect the two radius or ſemidiameters of the polygon at the points S and T; alſo draw the line R Q parallel to S T at the diſtance of nine fathoms, and interior to it; this laſt line likewiſe is to interſect the ſemidiameters of the place, and upon its extremities are deſcribed the tower-baſtions.

For the conſtruction of the tower-baſtions, make the demigorges Q L, M R, ſeven fathoms each; at the points M and L raiſe the perpendiculars for the flancs of the towers, and give to each five fathoms, and from the extremities draw the right lines to S and T to determine the faces of the towers; prolong the flancs of the towers inwards four fathoms and a half; then join theſe interior extremities by a right line, only leaving in the middle a paſſage nine feet broad for the entrance into each tower. Afterwards the perpendicular C D muſt be prolonged inwards, and from the point K, where it interſects the interior ſide Q R, ſet off K N five fathoms; then through the point N draw the indefinite lines M 1, L 2; prolong the flancs of the counter-guards inwards to interſect the lines M 1, L 2, at the points 1 and 2; draw the line 1, 2, for the re-entering part of the curtin, and P 2, Z 1, for the flancs;

flancs; thus the whole curtin M P 2 1 Z L is deſcribed. It is the curtin thus reinforced that occaſions the principal difference betwixt this and the forgoing ſyſtem; the defence of the faces and foſsès of the tower-baſtions is infinitely more vigorous by this conſtruction.

The foſsès of the towers are deſcribed as in the ſecond ſyſtem, and of the ſame breadth likewiſe.

The ſimple tenail, betwixt the two collateral counter-guards, ſuffers no alteration.

The foſsès of the counter-guards are drawn parallel to their faces, at the diſtance of 15 fathoms.

The capital of the half-moon is 55 fathoms, and its faces are directed upon thoſe of the counter-guard at 15 fathoms diſtance from the angle of the ſhoulder; its foſsè is 12 fathoms broad, and parallel to them.

The capital of the reduits, deſcribed within the half-moon, is 23 fathoms; its faces and flancs are deſcribed parallel to thoſe of the half-moon, with a foſsè five fathoms broad.

The flancs of the half-moon are deſcribed by taking ten fathoms upon their faces and ſeven upon the counterſcarp, and joining the two points of interſection.

The flancs of the reduit are formed by taking four fathoms upon its faces, and three upon the counterſcarp.

The covert way and glacis are not different from the former.

The terre plein of the rampart of the body of the place is ſix fathoms broad, including the breadth of the banquet; that of the counter-guards is of an equal breadth.

The terre-plein of the rampart of the half-moon, including alſo the breadth of the banquet, is four fathoms broad, and that of the reduits is only three fathoms.

The terre-plein of the tower-baſtions is raiſed 16 feet above the horizontal line; that of the counter guard 12 feet, which is the ſame height that is given to the curtins of the place.

The terre-plein of the tenail is not raiſed above the horizontal line, but the profils will ſhew all the meaſures for the heights and depths for all the works. PLATE 26.

The counter-guards, tenails, and half-moons are only half-lined, that their ramparts are not ſuſtained by maſonry above the horizontal line; at the top of the lining there is a berme ten feet broad, and all the rampart upwards, with the parapet, is covered with turf; upon the berme is planted a quickſet hedge, and behind it a row of palliſades, which prevents the aſcent of an enemy into the work, or the deſcent of deſerters into the foſsè. The parapet of the towers is of ſolid maſonry eight feet thick, and ſix feet high.

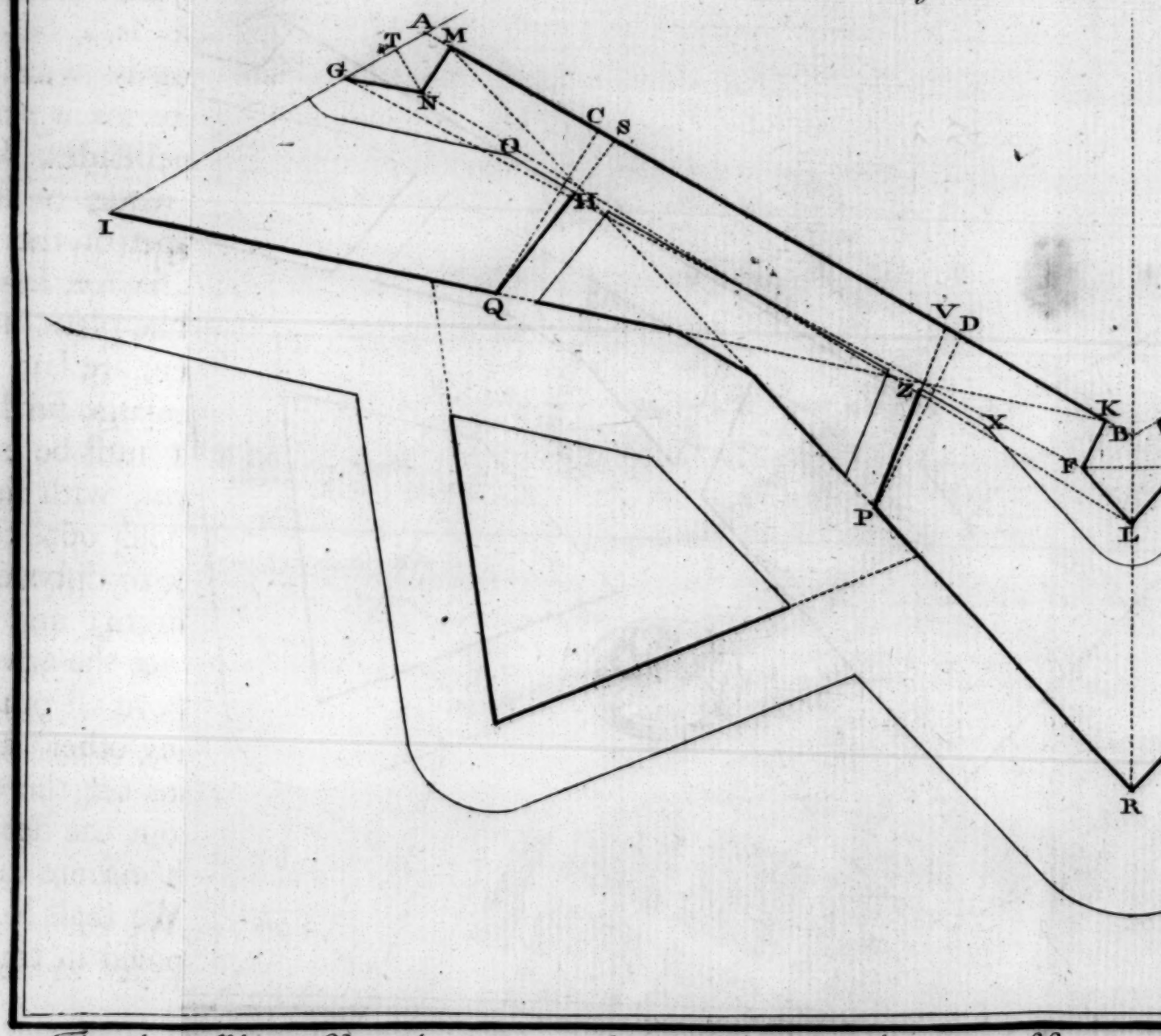
The plans and profils of the ſouterreins practiſed in this ſyſtem are laid down with ſuch accuracy, that it is needleſs to enlarge further upon this ſubject.

It muſt be owned that a place fortified according to this ſyſtem, with ſufficient garriſon, ſtores, *&c.* would be able to hold out conſiderably longer than any other method hitherto diſcovered, without being in danger of being taken by ſtorm; and altho' it is not entirely ſo perfected as it can be, yet the advantages peculiar to it ought to recommend it above all others; it does not need ſo numerous a garriſon as any other, and the circumference of the place remains entire till the enemy can mount his cannon, and batter it from the detached baſtions, which cannot be done but with infinite difficulty and loſs of time.

We ſhall have occaſion to ſay what amendment has been propoſed in this ſyſtem in concluding the following chapter.

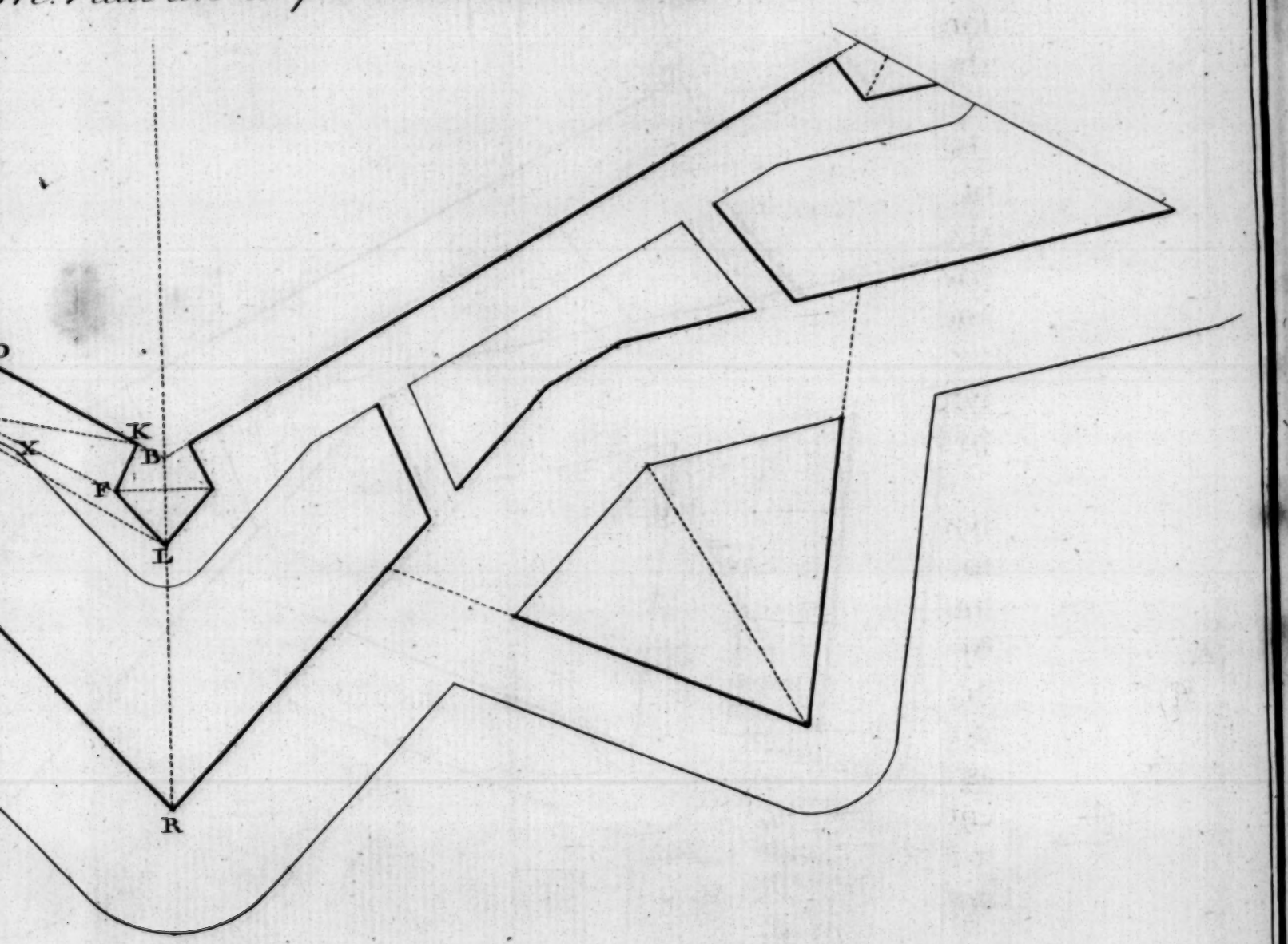
CHAPTER

The Second System of M. Vaub



The three Plates Numbers 24 to 26 are to be placed at page 88

M. Vauban as practised at LANDAW.



age 88

A Tower

Counterguard

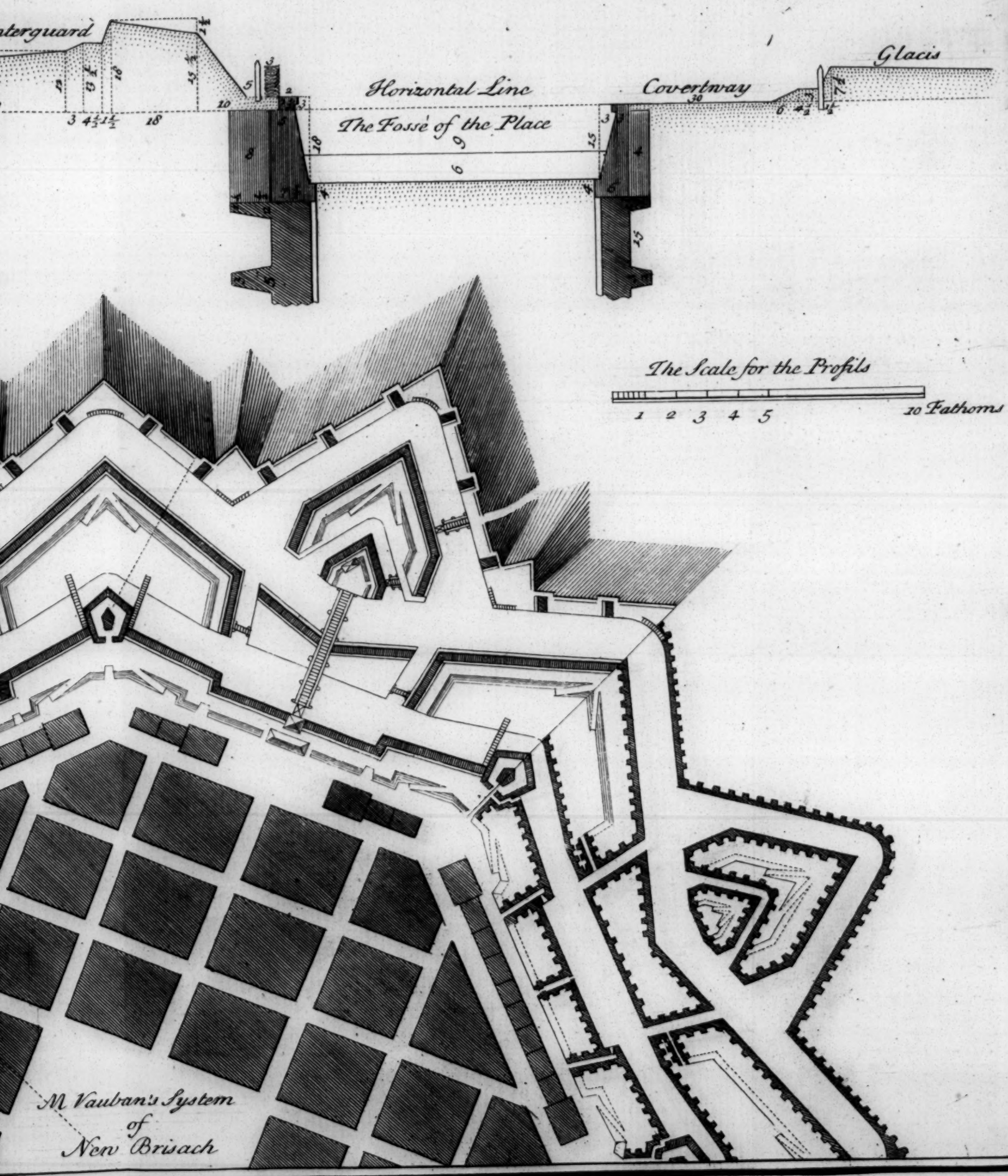
Terreplein

The Fosse of the Tower

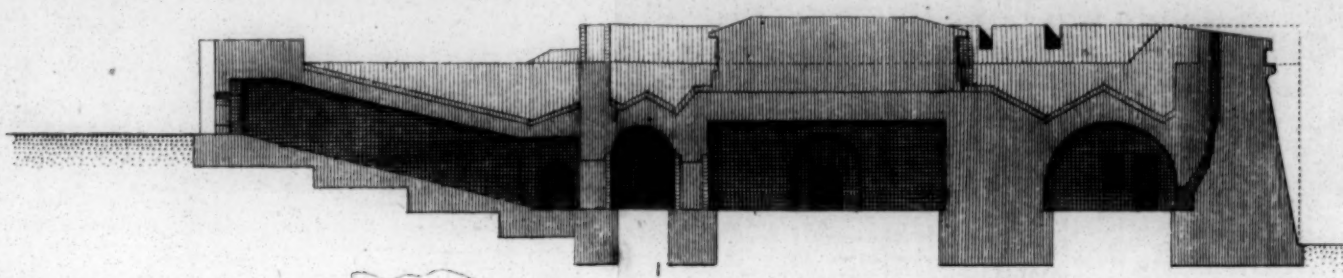
A Scale for the Plan

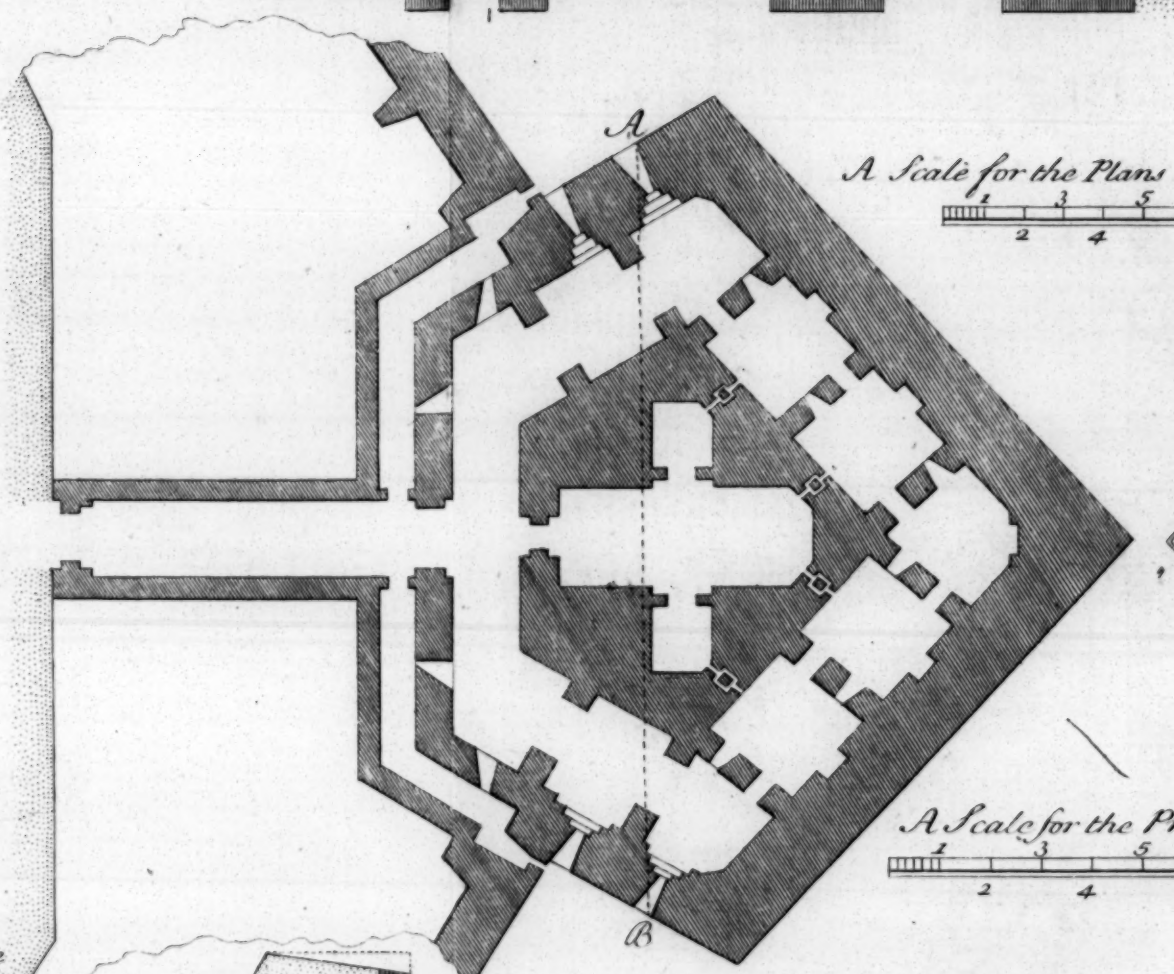
10 20 30 40 50 100 Fathoms

M. Vauban
of
New


terguard
Horizontal Line
The Fossé of the Place
Covertway
Glacis
The Scale for the Profils
1 2 3 4 5
10 Fathoms
M. Vauban's System
of
New Brisach

The Profil taken upon the capital of the Tower





A Scale for the Plans

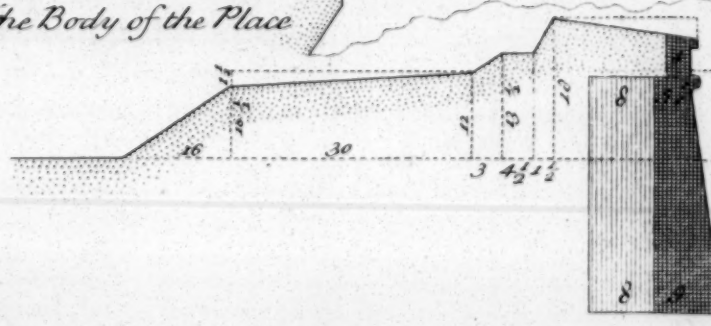
1 3 5
2 4

A Plan of the Tower taken upon the horizontal line

A Scale for the P

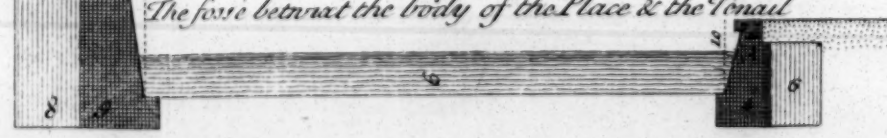
1 3 5
2 4

The Body of the Place



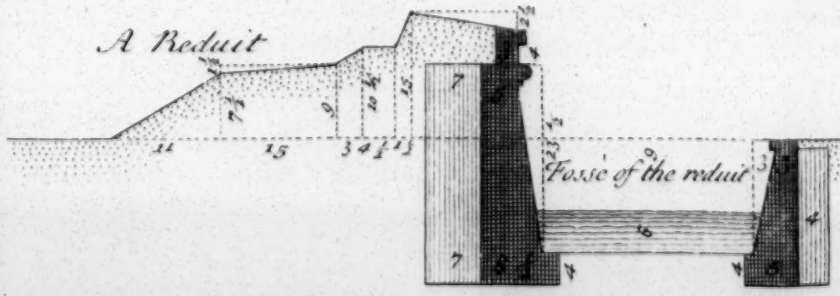
I. Profil taken upon the Curtin, Tenai

The fossé betwixt the body of the Place & the Tenail



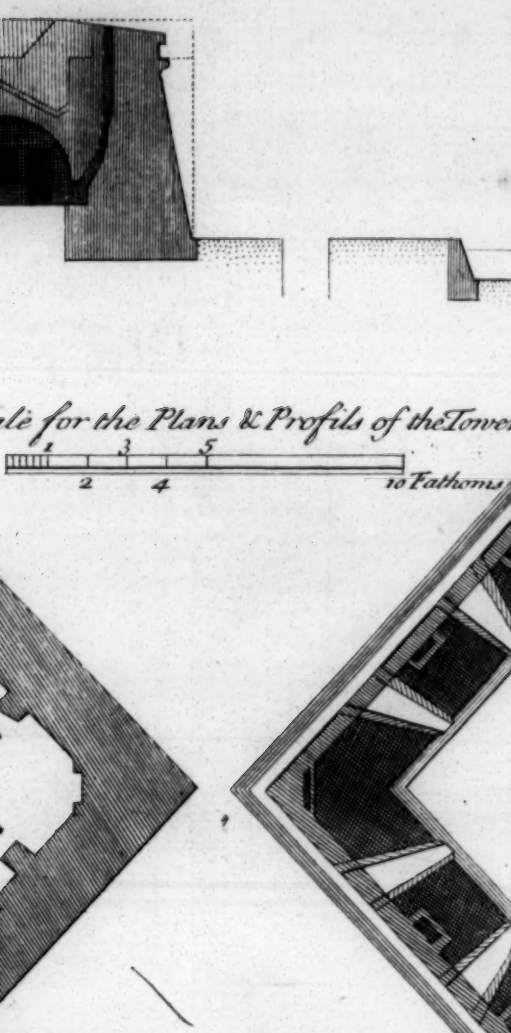
II. Profil taken upon the line r s of t

A Reduit



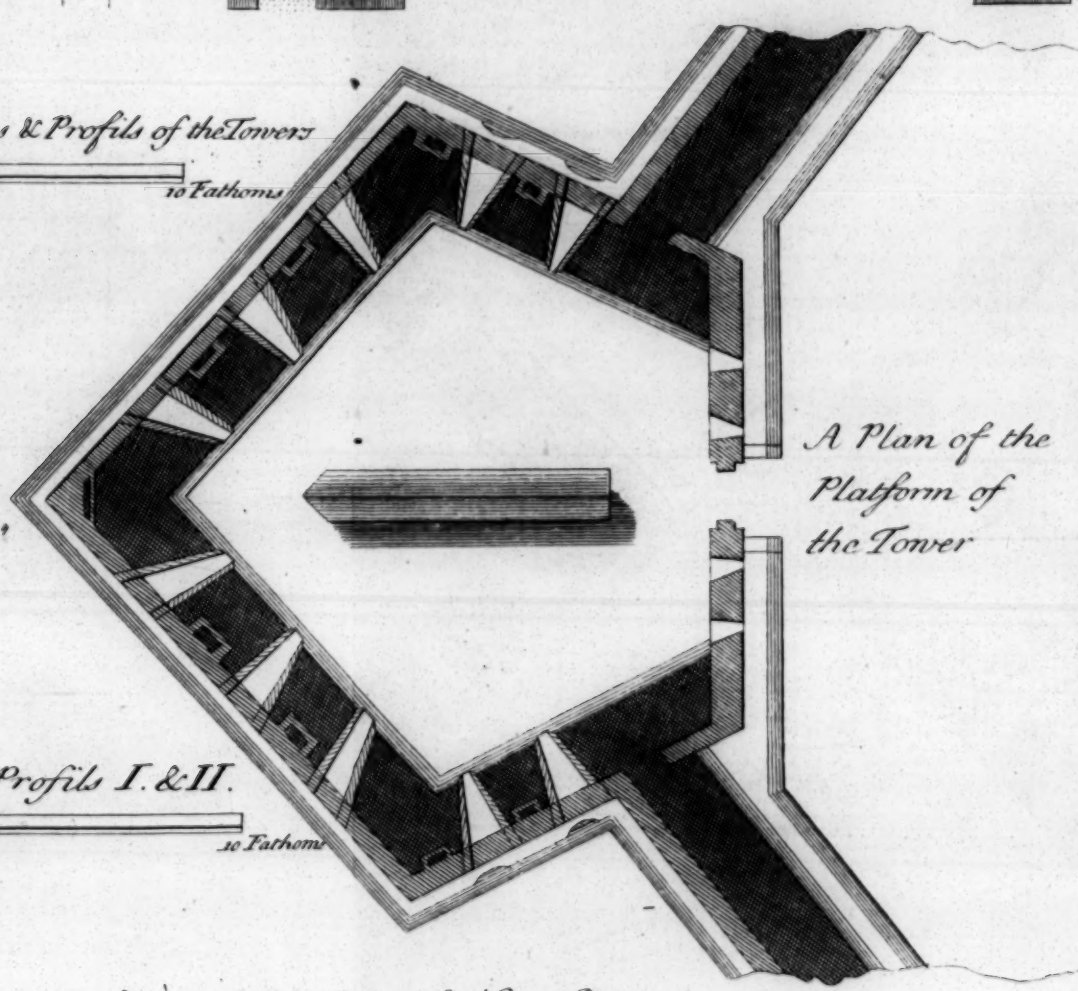
Half Moon

The Profil taken upon the Line A.B. of the Tower



lè for the Plans & Profils of the Towers

1 3 5
2 4 10 Fathoms

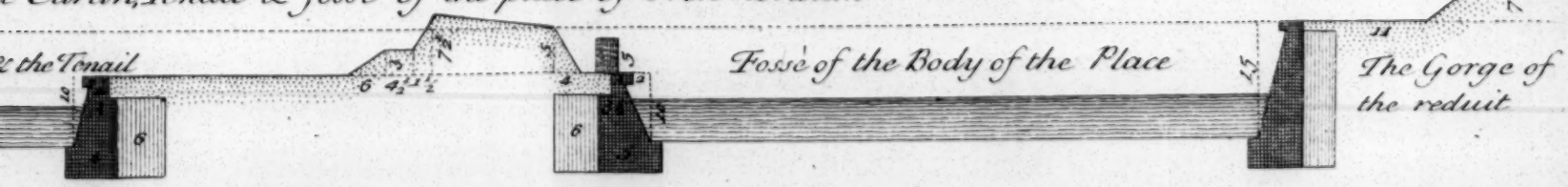


A Plan of the Platform of the Tower

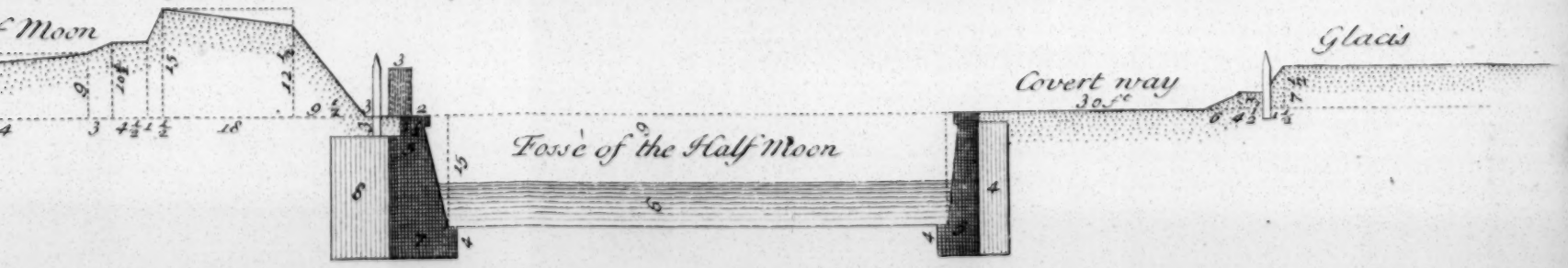
Scale for the Profils I. & II.

2 3 5
2 4 10 Fathoms

e Curtin, Tenail & fossè of the place of New-Brisach



he line r s of the reduit & Half Moon as marked in the Plan



CHAPTER IV.

THE SYSTEMS OF DIFFERENT AUTHORS.

WE come now to treat of the ſyſtems of different authors. By a due attention to this part of our treatiſe, the reader will be enabled to judge of the goodneſs or badneſs of any fortification, ſo as not to be deceived by every chimerical notion and falſe ſpeculation, which have only the appearance of reality, and ought never to be brought into practice.

Erhard's *ſyſtem.*

ERHARD, commonly called *Erhard* of *Bar-le-duc*, was Engineer to HENRY IV. of *France.* He fortifies within the given polygon in the following manner: from the ſquare to the octogon he makes the flanc perpendicular to the face, but in other polygons he makes it perpendicular to the curtin.

Suppoſe an hexagon whoſe center is O, and the exterior ſide A B; at the extremities A, B, with the radius A O, B O, make the angles O A C, O B D, each of them 45 degrees. If it was a ſquare you ſhould make them of 30 degrees, and if a pentagon of 40. In all other polygons, as in this, the author fixes them to 45. Fig. 1.

Divide the angle O A C equally in two by the line A D, that will cut the line of defence B D at the point D; likewiſe divide the angle O B D equally in two by the line B C, and that alſo will cut the line of defence A C at the point C; join C D, and that line ſhall be the curtin.

Laſtly, let fall perpendicular lines upon the lines of defence from the two points C D, thus you'll determine the flancs and faces.

For the foſsè, draw from each angle of the ſhoulder, lines parallel to the lines of defence, and make the breadth of the rampart equal to the length of the flanc.

Remarks on Erhard's *ſyſtem.*

The faults of this method are ſo conſpicuous when compared with the later fortifications, that ſome perhaps are inclined to believe that no ſuch ſyſtem was ever practiſed; but the time of its invention muſt be conſidered, and the manner of attack in thoſe days. The artillery brought before a town by the beſiegers conſiſted only in five or ſix pieces of cannon of very ſmall bores, with a few mortars that were fired more againſt the buildings of the town, than amongſt the beſieged in their works. The trenches, made without judgment, were neither ſpacious and broad, as they are contrived at preſent; for which reaſon the leaſt ſally overthrew every thing, and obliged the beſiegers to begin their work again, which was not to be done without much loſs, becauſe the fire from the town was ſuperior to their batteries. Thus time elapſed, and the approach of the bad ſeaſon, with the ill ſucceſs, often diſcouraged the beſiegers; however, if they ſtill perſiſted in their deſigns, and had, after infinite toil and bloodſhed, gained as far as the covert way, what could they attempt next, with their troops ſo fatigued and their ammunition almoſt ſpent, againſt a place whoſe garriſon had ſuffered little loſs, and whoſe ramparts and parapets remained almoſt entire? For the moſt part they were obliged to make a ſhameful retreat; or if they acquired a victory, it

was

was ſtill more cruel for the conquerors than the conquered. The hiſtories of thoſe times are full of examples of this nature; therefore if *Erhard* did not invent a more perfect ſyſtem, the neceſſity of a better defence did not oblige him to think of improving this art.

Our intention in inſerting this ſyſtem is, that we may judge of the improvement of fortification by comparing it with thoſe invented ſince.

The Italian *ſyſtem, according to* Pietro Sardi, *a* Roman *knight.*

THE *Italians* have various ſyſtems; we have choſe that of *Sardi* for an example, becauſe it has always been eſteemed preferable to the others of that nation.

He fortifies within the given polygon, and, according to *Oxanam*, makes his interior ſide 800 geometrical paces; but this abſolutely is ſome miſtake, and ought to be thus corrected.

Take each interior ſide AB of 133 fathoms, 2 feet; make the demigorges AC, DB, 25 fathoms each; the flancs CF, DE, muſt be equal to them, and erected perpendicular upon the curtin; divide the curtin in eight equal parts, and retain the two at each extremity thereof for the ſecond flancs CI, DH, from which draw the lines of defence ſichant to paſs at the extremities of the flancs, whereby the faces EK, LF, are form'd; this is only practiſed thus for the firſt ſeven polygons, for in the octogon you muſt take two of thoſe eight parts for the ſecond flancs, and in all ſuperior polygons half of the curtin is required. Fig. 2.

The cavaliers which this author places in the middle of the curtin, are 30 feet diſtant from the parapet; their figure is a parallelogram; on their longeſt ſide are placed

three pieces of cannon to ſcour the field, and on their two ſhorteſt ſides are placed four pieces of cannon, two on each, to fire in the baſtions whenever the enemy had made a conſiderable breach in them.

For the orillon and low flancs, or caſemates, he takes
Fig. 3. upon the flancs A C, E F, each equal to a third of the flanc; and upon the demigorges B I, N M, equal to A C, E F; and carries theſe lengths upon the faces prolonged from A to L and from E to H; after this he draws the lines I T, L V, M O, H R, parallel to the flancs, and indefinite; he then prolongs the flancs inwardly, ſo that B S, M Y, may each be 15 feet, and from the points S and Y draws S P, Y Q parallel to the demigorges; the parts C 4, F 3, have each 10 feet, and the lines P 6, Y 5, have each 24 fathoms.

If the orillon is deſigned to be ſquare, from the point F draw a line to fall upon the middle of the face of the oppoſite baſtion, which will interſect at R the line H R; and for a round orillon, after having drawn the line C V, in the ſame manner as F R, make upon L V an iſoſceles triangle, whoſe ſides may be about the two thirds of the ſaid line L V, and from the ſummit of this triangle deſcribe the roundneſs of the orillon. The line P 6 ſhews the exterior extremity of the upper flanc, and C B the ex-
Fig. 4. terior extremity of the lower flanc or caſemate; the profil of the two is deſcribed. M. *de Vauban* juſtly condemns the uſe of two flancs ſo contiguous one to the other, for it is impoſſible to occupy the lower flanc, ſince the fire and dexterity of the beſiegers is ſo much increaſed as it is of late in the ſerving their cannon and mortars.

Remarks

Remarks on the Italian *ſyſtem.*

The objections that can be made againſt this ſyſtem are, that the flanked angles become too acute, and the faces are defended too obliquely from the flanks, which nevertheleſs are eaſily to be diſcovered by an enemy, becauſe of the ſecond flanc upon the curtin; however, this method is followed by all the *Italian* authors, and their reaſon for making the flanked angle acute is, that the faces of the ſame ſide of the polygon may mutually ſerve to flank each other.

The Spaniſh *method of fortification.*

THE *Spaniards* entirely reject the ſecond flanc, and the angle of the baſtion becoming obtuſe, is not reckoned by them any fault in fortification. According to this ſyſtem, you muſt make the demigorges A C, B D equal to the ſixth part of the interior ſide A D, which is ſuppoſed to be 120 fathoms. The flancs are equal to the demigorges, and are erected perpendicular upon the curtins. The faces are determined by the lines of defence razant C E, B F. Fig 5.

Remarks on the Spaniſh *ſyſtem.*

The flancs likewiſe in this ſyſtem afford too oblique a defence to the faces, but are not ſo much expoſed, there not being any ſecond flancs; and the angles of the baſtion in all polygons above the hexagon, become greatly too obtuſe, which are to be rejected, becauſe an equal breach is made with more eaſe in an obtuſe angle than in an acute angle;

angle; for let the breach A B be equal to the breach C D,
Fig. 6. there is required leſs trouble to make the demolition A E B than to demoliſh the triangle C E D. For this reaſon ſome authors have maintained that all acute angles were to be approved, but they are much to blame, becauſe, as we have demonſtrated in a former ſection, a flanked angle that is too acute cannot withſtand the enemy's cannon.

Of the reinforced order.

THIS ſyſtem bears the name of the *reinforced Order* becauſe of the reinforcement of its line of defence. The interior ſide is ſuppoſed to be 160 fathoms, ſo that the great line of defence would be much too long for the uſe of the musket. Several *Italian* and *Spaniſh* authors have treated this ſubject, but we ſhall here ſet it down as it is mentioned in father *Bourdin*'s book of fortification.

Fig. 7. Divide the interior ſide A B into eight equal parts, each demigorge has one of them, as likewiſe each flanc, which is made perpendicular upon the curtin; make D E and F C each equal to two of thoſe parts; the retired flancs E I, F L, are equal and parallel to the flancs of the baſtions; join I L, and you'll have the retired curtin; then for the faces draw the lines of defence I F G, L E H.

Remarks on the reinforced order.

All the defences of this ſyſtem are too oblique, the flanked angles too acute, and the foſsès to be well defended ought to be extremely broad, ſince they muſt be made wide enough at the flanked angle that the enemy may not advance too eaſily towards the breach, and they muſt

muſt be directed to the angles of the ſhoulder that they may be defended from the flank, but this makes them become very large, and prodigiouſly increaſes the expence.

The Dutch *method of fortification according to* Marolois.

SEVERAL *Dutch* authors have wrote concerning this art; the moſt worthy of notice is *Marolois*, whoſe ſyſtem we ſhall here lay down.

Let A B be the exterior ſide and indefinite; make at the point A the angle B A F, equal to half of the angle of the polygon you intend to fortify; for example, let us take an hexagon and make the angle B A F of 60 degrees, becauſe the angle of an hexagon is 120 degrees. Divide that angle equally in two by the line A C, and then make the angle C A D ſeven degrees and an half; carry upon the line A D 48 fathoms from A to E for the face of the baſtion; from the point E draw the line E G indefinite at rectangles with the exterior ſide, and at the ſame point E make the angle G E F of 50 degrees; from the point F, where the ſemidiameter is interſected, draw the line F H parallel to the exterior ſide, which will terminate the flanc and make the curtin G H 72 fathoms; from the point H raiſe the perpendicular H I, make I B equal to A N, and the flanc H L equal to the flanc G E; draw the face L B, and after having made the demigorge H M equal to the demigorge F G, draw the ſemidiameter B M O, which will interſect the former A F O at the point O; this will give you the center of the polygon, which you may compleatly finiſh by deſcribing a circle which will touch the points A B, and wherein you can deſcribe an hexagon by carrying A B ſix times round its circumference; then from each angle of the exterior polygon carry on both ſides thereof

Fig. 8.

thereof the diſtance A N, and raiſe the perpendiculars thereon to carry the diſtances N E, E G, to determine the faces, the flancs and the curtins.

This manner of ſtructure ſerves for all polygons up to the endecagon; but for the dodecagon, and thoſe above it, you muſt, after having made the angle B A O equal to half the angle of the polygon, make the angle O A E of 45 degrees, that the angle of the baſtion might not become obtuſe, which it infallibly muſt if you don't obſerve this precaution, but only added to half the angle of the polygon ſeven degrees and an half on each ſide. The author has not given any hint concerning this, yet it appears very plain, for the greater the polygon is the more obtuſe are its angles, and the angle of the baſtion increaſes likewiſe, and at laſt would intirely be out of all proportion.

Remarks on the ſyſtem of Marolois.

The faults of this method are evident from what we have already ſaid concerning ſome of the foregoing methods; we ſhall only add, that the *Dutch*, beſides the falſe-bray that we have before ſpoke of, have another peculiarity in their works, *viz.* a *chemin des rondes*; this is a ſpace of nine feet broad juſt upon the cordon of the wall, with a little parapet wall with murdreſſes on the exterior ſide; it is made for the patrol to go their rounds in the night, without being in danger of falling into the foſsè; but the inconveniencies it occaſions in the time of a ſiege have made M. *de Vauban* condemn it intirely, for very ſoon the little parapet is ſhatter'd to pieces, which pieces annoy the men upon the works, and do them a great deal of miſchief; moreover the ſpace is quickly fill'd up by the ruins that fall from the parapet of the place.

The

The chevalier De Ville's *ſyſtem.*

THIS noted author fortifies a polygon after the *Spaniſh* method, taking the ſixth part of the interior ſide for his demigorges and flancs. In the ſquare and pentagon he determines the faces and flanked angle by drawing the lines of defence razant. In other polygons he draws Fig. 9. a right line A C from each extremity of the flancs, from the middle of which, as center, he deſcribes a ſemicircle A B C, which is interſected in two equal parts at B, at which point he forms the angle of the baſtion by joining A B, B C; hereby he makes a ſecond flanc upon the curtin, according to the *Italian* ſyſtem. This method therefore is by ſome called the *compoſite*, becauſe it partakes both of the *Italian* and *Spaniſh*.

For the orillon and caſemates, divide the flanc A B Fig. 10. equally in two, as at C; draw the line D C from the flanked angle D of the oppoſite baſtion, make C E and A F ſix fathoms long, join E F, and thereon make a ſemi-circle if you would have a round orillon; if a ſquare one, let the line E F ſerve to determine the orillon.

For the caſemates and high flanc, let E C be prolonged indefinitely, and from the extremity I of the oppoſite orillon draw I B alſo indefinite; divide the demigorge equally in two at H, and draw through it the line L O parallel to B C; the interſection of L O with the indefinite line will determine them. The interior ſide is taken for a ſcale, being firſt divided into 120 fathoms.

What remarks have been given for the preceding ſyſtems may be applied to this. We ſhall add, that in this method there is one more conſiderable fault, *viz.* the flancs being too ſmall to afford a ſufficient battery.

All the ſyſtems we have hitherto given make us apt to believe, that the chief uſe of the flanc was to defend the paſſage of the foſsè. In thoſe times, when the attacks were very imperfect, the enemy made uſe of wooden galleries to paſs the foſsè, againſt which the cannon of the town had fine play; the flanc indeed could hold but four or five guns, but as others could be tranſported from parts that were not attacked, ſo as to make a continual fire, firing ſome whilſt the reſt were loading, the enemy was much perplexed, for the artillery that was in the field was greatly too trifling to attempt ſilencing the batteries of the town.

Afterwards the beſiegers artillery becoming more numerous and terrible, it was thought proper to make a ſecond flanc and caſemate, the one to deſtroy the galleries, and the other to endeavour to diſmount the beſiegers cannon; thus the defence was ſtill proportionable to the attack. But ſince thoſe days, that whole arſenals are marched up againſt a fortreſs, and that the paſſage of the foſsè is brought about by faſcinage and ſacks of earth, in defiance of all the fire from the flanc, it is in vain for the beſieged to extend or multiply their flancs; theſe defences are intirely overthrown even in the very beginning of a ſiege. The prodigious ſhowers of granades, ſtones, and bombs, which fall among them, the terrible effect of mines which ſpring on all ſides, the inceſſant and terrible fire from many thundering batteries that tear up from its foundation the only defence which they look'd upon as their laſt reſource, all threaten them with approaching deſtruction, and the only thought they can have, after having made as ſtout a defence as poſſible, muſt be to obtain a glorious capitulation, unleſs ſome powerful army comes to their aſſiſtance, or that ſome dreadful ſtorm and tempeſt act miraculouſly in their favour.

The

The Count of Pagan's *ſyſtem.*

COUNT *Pagan* fortifies within the polygon, and diſtinguiſhes three ſorts of fortification; the *great*, the *mean* ſort, and the *leſſer*; the exterior ſide for the great ſort is fixed at 200 fathoms, the middle ſort is allowed 180, and the leſſer 160. He begins by erecting upon the middle of the exterior ſide, inwards, a perpendicular always of 30 fathoms for all polygons above the ſquare; and after having drawn the lines of defence to paſs at the inner extremity of the perpendicular juſt mentioned, he meaſures out upon thoſe lines 60 fathoms for each face of his great fortification, 55 for thoſe of the middle ſort, and for the ſmall he only allows 50; and from the extremity of each face he draws a perpendicular upon the oppoſite line of defence, and thus he terminates his curtin of flancs; but theſe rules, and eſpecially the perpendicular, vary ſomewhat for ſquares, as may be ſeen in the following table.

	The Great Fortification		The Mean Sort		The Leſſer	
	For Squares	For all other Polygons	For Squares	For all other Polygons	For Squares	For all other Polygons
Exterior ſide	200 fath.	200 fath.	180 fath.	180 fath.	160 fath.	160 fath.
The Perpendicular	27	30	24	30	21	30
Face	60	60	55	55	45	50
Flanc	22	24 : 2 *ft.*	19 : 1 *ft.*	24	18 : 3 *ft.*	23 : 2 *ft.*
Curtin	73 : 2 *ft.*	70 : 5 *ft.*	63 : 4 *ft.*	60 : 4 *ft.*	63 : 5 *ft.*	50 : 4 *ft.*
Line of defence	141 : 4 *ft.*	141 : 2 *ft.*	126 : 1 *ft.*	126 : 5 *ft.*	115 : 5 *ft.*	112 : 3 *ft.*

By what we have juſt now ſaid, and by the aſſiſtance of this table, it is not at all difficult to trace out the magiſtral line of any polygon according to this ſyſtem.

The orillon, which the author makes ſquare, is always equal to half the flanc. The retreat of the curtin is taken
Fig. 11. upon the line of defence prolong'd, and that of the orillon is drawn parallel to it. The three places of each flanc, the high one and two lower ones, are elevated two fathoms one above the other, as X X, Fig. 13. and their terre plein, together with the parapet, is ſeven fathoms in the ſquare of the great fortification; in the ſquare and pentagon of the middle ſort; and in the ſquare, pentagon, and hexagon of the ſmall; but in all others the ramparts of the caſemates are allowed eight fathoms, although the other ramparts of the place are to have no more than ſeven.

For all ſquares, and for the pentagon of the ſmall fortification, the loweſt caſemate is deſcribed upon the line of the high flanc, which is fourteen fathoms long. In the other polygons, the firſt caſemate is carried inwards five fathoms, and the ſecond and third are each 15 fathoms in length.

In all polygons there muſt be drawn, from the outward extremity of the high flancs, lines parallel to the faces of the baſtions, whereby you form an interior baſtion; and betwixt the faces of the outward and inward baſtion, there muſt be made a dry foſsè to diminiſh the effects of the enemy's mines.

The foſsè of the place is 16 fathoms broad before the faces, and is drawn parallel to them; its depth is three fathoms. The height of the ramparts is ſix fathoms above the bottom of the foſsè; that of the exterior baſtion is the ſame.

The out-works, which are called by the author the *great counterſcarps*, have two different diſpoſitions.

The firſt conſiſts in a double ravelin, and a counter-guard or cover-face. The demigorges of the great ravelin

are

are each 30 fathoms, the faces 50; the faces of the little ravelin are parallel to them at the diſtance of 15 fathoms; there is a ſmall foſsè betwixt theſe two ravelins. The outward foſsè of the ravelin and counter-guard is 12 fathoms broad, and the thickneſs of the ſaid counter-guard nine or ten fathoms.

The ſecond diſpoſition of the out-works conſiſts in two counter-guards joined together by a curtin-briſée, at whoſe extremities are made two flancs. It is deſcribed as follows. Take 25 fathoms for the breadth of your counter-guards, and having continued their faces till they interſect the counterſcarp of the place at the points A B, take from A to C and from B to D 17 fathoms for the depth of the three caſemates, and raiſe perpendicular flancs at the point D and C. The ramparts of theſe out-works, and of the others, are ſeven fathoms thick; what ground then remains is occupied by ſuburbs, *&c.* Fig. 12.

The height of both theſe ſorts of out-works is four fathoms above the bottom of the outward foſsè, which is but two fathoms deep; this makes the ramparts of the place to be not more than one fathom above them. The covert-way is four fathoms broad, and what remains is finiſhed in the uſual manner.

Remarks on the Count of Pagan's *ſyſtem.*

The great and manifold advantages of this ſyſtem above all others that had ever appeared till then, drew in many admirers, who eſteemed it by much the beſt method of fortification; and had it not been for M. *de Vauban*'s ſyſtem, its reputation would ſtill have been kept up. In effect, the method of deſcribing the flancs is infinitely ſuperior to what was before practiſed; the double baſtions, whereby

whereby the author pretends to ſtop the progreſs of mines, and render them uſeleſs; the ſuburbs, which can contain a great number of people and neceſſary cattle, who are troubleſome in a beſieged place, and otherwiſe would require a horn or crown-work to cover them, that often produce very fatal conſequences; laſtly, the retrenched half-moons have ſomething ſo ſtriking, eſpecially to ſuch perſons who have not ſeen any thing better, that it is very eaſy to be carried away with a falſe notion, without taking notice of the errors of this fortification, which however are not ſo inconſiderable as one would be apt to imagine. The flancs, whoſe defence is intirely direct, ſeem at firſt to admit of no better diſpoſition; but as it is of the greateſt importance to preſerve, as much as one can, theſe parts, which are the only ones that can be made uſe of to flanc the breach, and defend the paſſage of the foſsè, they are greatly mended by M. *de Vauban*'s diſpoſition of them; whereby alſo the enemy has not the advantage to batter them upon ſo large a front. The orillons are of a prodigious ſize, and render the ſpace of four or five fathoms uſeleſs, wherein two cannons more might be placed. The height of the caſemates, one above the other, is not ſufficient to allow them to fire all at once, and beſides they are too narrow. Such ſort of pieces, as obſerves the author of the anonymous ſyſtems (which we ſhall lay down hereafter) are only good to exerciſe the skill, and cauſe the diverſion of the bombardeers, who have the ſatisfaction to ſee all their throws anſwer their expectation. But as to this, it may be believed that the Count *de Pagan* would have corrected them himſelf, if in his times he had ſeen bombs thrown with ſuch profuſeneſs and dexterity as they are now-a-days. The interior baſtion is only flanked by the caſemates, which cannot hinder the miner to fix himſelf at the angle

of

of the ſhoulder. Laſtly, the curtin briſée of the ſecond ſort of out-works deprives their flancs of all defence, and thoſe ſuburbs within them ſerve to retrench the enemy, if taken. It is no eaſy thing to lay down all the faults of any one method, it would be too tedious, and it may ſuffice to obſerve the principal ones, to ſhew that it is not without reaſon that we think thoſe of Marſhal *de Vauban* to be the moſt preferable; not that they ought to be eſteemed ſo perfect, but what they are capable of being corrected and amended. Time and uſe diſcover defects and errors in all ſublunary things, but the love of novelty ought never to betray us into any chimerical notion, till we are ſenſible the change would be for the better.

The ſyſtem of Monſieur de Bombelle.

M. *De Bombelle* eſtabliſhes three ſorts of fortification; the *great royal*, the *middle*, and the *ſmall royal*. The interior ſide of the firſt he fixes at 80 *rhynlandt* perches, or 160 fathoms; the ſecond at 70 *rhynlandt* perches, or 140 fathoms; and that of the third at 60 *rhynlandt* perches, or 120 fathoms; and all three are fortified after the ſame manner.

Let the line *a c* be the interior ſide of the polygon; Fig. 14.
give the fifth part thereof to each demigorge *a b* and *d c*, and the fourth part thereof to each flanc *b i*, *d l*, making an angle of 100 degrees with the curtin; then draw the lines of defence razant *d p*, *b s*, to determine the faces.

For the orillons and caſemates, draw the line *b n* perpendicular upon the extremity of the curtin; take the third thereof, which ſet off from *n* to *u*; ſet off alſo upon the oppoſite face a third thereof from *s* to *z*, and from *z* draw the

the line *x u o* that will be determined at *o* by the line *b o*, perpendicular to the line of defence.

Continue the line of defence till it interſects the ſemi-diameter of the polygon at *x*, make *x* M equal to *x a*, then join *b* M by a right line that will ſerve to determine the covert flancs; the center *q* of theſe flancs is found at the ſummit of a little iſoſceles triangle, whoſe baſe is *b o*, and its ſides each of them equal to three fourths of its baſe. The high and low flanc exceed the point *o* towards the face two or three fathoms.

The caſemate of the flanked angle is deſcribed by taking upon the capital *p t*, equal to *p r*; the center for the curve is taken in the middle of *p t*.

The flanked angle of the half-moon is found by deſcribing two arches interſecting each other, one from the point *d* with the interval *d a*, the other from the point *b* with an equal interval *b c*. The faces are drawn to the extremities of the orillons, and are fixed by the counterſcarp of the foſsè that is 24 fathoms broad. We have made the interſection for the flanked angle of the half-moon with the ſame intervals, but have taken through inadvertency the points *a*, *c*, for centers. We have marked this variation in the plan by the figure *y y y*.

The foſsè of the half-moon is 16 fathoms over; the counter-guard is deſcribed by prolonging the faces of the half-moon indefinitely, beyond its foſsè; ſo that the line 1, 2, may be made equal to one of its faces, the angle 1, 2, 3, ought to be 60 degrees; make 1, 5, the third part of the whole line 1, 2, then nothing remains but to finiſh the ſmall rhombus 1, 4, 5, 6, as is ſhewn in the figure. The foſsè of the counter-guard is the ſame breadth as that of the half-moon. All the parapets for this ſyſtem are four fathoms broad, and the rampart ten fathoms.

Remarks

Remarks on the ſyſtem of Monſieur de Bombelle.

This method is more conformable to the maxims of a good fortification than any of the preceding ones; its faces are defended very directly, and the flanks being very large, are capable of affording a good defence without preſenting to the enemy ſo large a front, becauſe of their line being always razant. Nevertheleſs, as the diminiſhed angle is always of about 21 degrees, it happens that the flanked angle of the ſquare is but 48 degrees, and that of the pentagon but 66 degrees; this renders the firſt intirely irregular, and the ſecond extremely weak; moreover the caſemate of the flanked angle weakens it much more than it at firſt ſeems to ſtrengthen it; for firſt, as the caſemate is to be made about three fathoms lower than the high place, if one would prevent thoſe that are below from being burnt by the cannon that is above them, which accident has frequently happened, it is impoſſible but that it muſt be enfiladed on all ſides, eſpecially not being covered by any out-works; and ſecondly, the convexity of the high place at the flanked angle preſents a much eaſier front for the enemy to batter than the point of the baſtion would be; laſtly, the caſemates ſerve as ſteps for the enemy to mount more commodiouſly the breach.

The entrance into the baſtion at the gorge would become more ſpacious and convenient, if the concavity of the flancs was deſcribed after the uſual method.

The ſyſtem of Monſieur Blondel.

M. *Blondel* fortifies within the given polygon; he eſtabliſhes two ſorts of fortification; the *great one*, whoſe exterior ſide is 200 fathoms; and the *leſſer one*, where the exterior ſide is but 170 fathoms; becauſe he will not have the line of defence exceed 140 fathoms, which is the greateſt muſquet-ſhot, nor leſs than 120 fathoms, not to increaſe the number of baſtions.

He begins by the diminiſhed angle, which you'll find by taking 90 degrees from the angle of the polygon, and by adding 15 degrees to the third of the remainder, as for example:

	120 *deg.*	angle of the polygon in a hexagon.
Subſtract	90	
Remains	30 *deg.*	third thereof is 10
		to which add 15
		25 *deg.* for the diminiſh'd angle in a hexagon.

But in a ſquare it is 15 degrees, and increaſes little by little in the other polygons up to thoſe baſtions that are made upon a right line, where it happens to be 45 degrees. Hence it follows that the flanked angle in a ſquare is 60 degrees, in a pentagon it is 66, in a hexagon 70, always increaſing as the polygons increaſe; though it never is 90 degrees but in thoſe baſtions that are deſcribed upon a right line.

Let A B be the exterior ſide of an hexagon, at each ex-
Fig. 15. tremity make the diminiſhed angles A B C, D A B, each of 25 degrees; thus you may draw the two lines of defence A D and B C, which are to be determined by giving to each

each of them ſeven tenths of the exterior ſide, which for that purpoſe muſt be divided into ten equal parts; and whether the fortification be of the great or ſmall ſort, the lines of defence always anſwer reſpectively, according to the meaſures above laid down; divide A O and B O equally in two at the points E and H, and from theſe points draw E C, H D, to form your flancs and faces, then join C D for the curtin.

For the orillon, take upon the flancs E I and H L, each of them 10 fathoms, and for the retreat thereof allow five or ſix fathoms, which muſt be drawn from the point of the oppoſite baſtion. In greater polygons, the author inſtead of ſix fathoms gives even 20 fathoms for the retreat of the orillon, that thereby his curtins may not be too ſhort. The three platforms which are deſcribed after the retreat of the orillon are drawn parallel to the flancs; their parapets are three fathoms thick, and their terre-plein five fathoms. The loweſt of the three is about 9 or 12 feet higher than the bottom of the foſsè, the next 18 or 24 feet, and the third 27 or 36 feet from the ſaid bottom. The gorge of the baſtion is taken up by a cavalier, as may be ſeen in the figure, whoſe terre-plein and parapet are the ſame as thoſe of the platforms.

The foſsè is parallel to the faces, and its breadth is equal to the length of the flancs. At the point of each baſtion, having taken 10 or 12 fathoms in the counterſcarp, make a counter-guard (deſigned to be of brick-work or maſonry) four fathoms thick, including the parapet, which is allowed no more than eight or ten feet. This work is ſuppoſed to be full of countermines; its faces are parallel to thoſe of the baſtion, and are determined by the foſsè of the half-moon.

The flanked angle of the half-moon is found by deſcribing two arches from the points E H as centers, with the diſtance of E to H for the common interval; the faces are drawn to points ſix fathoms above the angles of the ſhoulder, and are determined by prolonging the exterior ſide of the counter-guard; the foſsè is ten fathoms broad, and that it may be the better defended, there is deſcribed upon each face of the baſtion, juſt upon that part that diſcovers the whole breadth of the foſsè, two batteries one above the other; the like batteries are alſo made at the extremity of the faces of the half-moon, as far as they diſcover the foſsè of the counter-guard; the little half-moons placed at the re-entering angles are deſigned to cover theſe batteries, whoſe demigorges and faces are allowed 20 fathoms. Laſtly, there runs along the middle of the great foſsè a cuvet ſeven or eight fathoms broad.

Remarks on the ſyſtem of Monſieur Blondel.

If the only thing required in fortifying a town was the placing of a prodigious number of cannon upon the ramparts, nothing could be better imagined than this ſyſtem, wherein each face is flanked by four batteries, every one of 50, and even 60 and 70 fathoms long. But as a picture that ſhould fail againſt any of the rules in painting, ought to be condemn'd, although its colours were ever ſo bright and lively; ſo likewiſe this prodigious augmentation of fire that is offered to us in this ſyſtem ought not to dazzle our eyes, and make us ſhut them upon the eſſential errors thereof, and which run through the whole intirely againſt one of the moſt fundamental maxims of this art.

The

The counter-guard of maſonry, as the author deſigns it, cannot reſiſt a long while, becauſe the thickneſs of the parapet is no more than eight or ten feet, and there is not place enough to ſubſtitute another of gabions or ſacks of earth, which neceſſarily muſt be allowed three fathoms and a half to be able to withſtand the ſhock of the cannon; this counter-guard being deſtroyed, the flancs are quite expoſed to the enemy's batteries, without being able to fire all their cannon at once, becauſe the ſmall diſtance there is allowed from the places above to thoſe underneath them, endangers the men which are in the lower ones of being burnt; moreover, theſe four batteries are ſo placed in a heap together, that the bombs thrown in amongſt them would ſoon make a ruined amphitheatre, that would at once invite the enemy to an aſſault, from the facility wherewith he could certainly expect to aſcend it.

The batteries that are upon the faces of the baſtions, and of the half-moons, are liable to the ſame accidents. Another objection againſt this ſyſtem, is the acuteneſs of the flanked angle, which in almoſt all the polygons is found to be ſuch; and the dry cuvet, very juſtly called by a modern author a *miner's niche*, is without doubt to be rejected, notwithſtanding M. *Blondel* has placed in the re-entering angle thereof a caponiere. Several other objections there are, which would take up too much time to mention, beſides the expences, which, as vaſt as they would be, ought not to enter into conſideration if the works were anſwerable, becauſe, as obſerve the chevalier *de Ville* and Count *Pagan*, a prince ought to open his purſe, and ſhut his eyes whenever he fortifies any place whereon the ſafety and ſurety of his realms depends.

The

The three ſyſtems of an anonymous author.

Firſt SYSTEM.

TOWARDS the end of the laſt century, in the year 1689, there was publiſhed a book, intitled, *Nouvelle maniere de fortifier les places, tirée des méthodes du chevalier de* Ville, *du comte de* Pagan *& de M. de* Vauban, *avec des remarques ſur l'ordre renforcè, ſur les deſſeins du capitaine* Marchy *& ſur ceux de M.* Blondel. Therein are contained ſuch ſolid reflections concerning theſe ſyſtems of fortifications, that it is ſurpriſing the author would not prefix his name to a work that would have gained him univerſal applauſe.

It is upon theſe reflections that he grounds his new ſyſtem, which, as he owns himſelf, at firſt only appears to be a medley, compoſed of pieces taken from different authors; but by his judicious choice and diſpoſition of them, increaſe infinitely more the ſtrength of a place than any of the ſaid ſyſtems could do ſeparately, and at the ſame time diminiſh the expence.

He diſtinguiſhes three ſorts of fortifications, the *great*, the *mean*, and the *ſmall* ſort; in each of which the ſtructure is ſo different, according to the different polygons, that it is proper, before we come to a further explanation, to ſubjoin here a table, thereby to have at one view the different references of the pieces; this the author has neglected, but it is greatly uſeful to render his ſyſtems more intelligible to the reader.

Great

Great fortification.

Polygons	IV.	V.	VI.	VII.
	fathoms	fathoms	fathoms	fathoms
Interior ſide	130	140	150	150
Demigorges	25	28	28	30
Right-angled flanc	Un-deter-min'd.	24	25	25
Inclination of the flanc	0	3	3	3
Second flanc	0	12	14	Un-deter-min'd.
The right ſally of the orillon	1	1	1	1
Retreat of the orillon as far as the caſemate	1	1	1	1
Retreat of the curtin as far as the caſemate	1	0	0	0
Caſemate	ſquare	ſquare	round	round

1. All the polygons above the heptagon have the ſame dimenſions as the heptagon, excepting with reſpect to the demigorges, for which there muſt be added as many feet to the fifth part of the interior ſide as the number of degrees the angle of the polygon has above 135 degrees.

The ſecond and third remarks relate to the *mean* and *leſſer* fortification.

Mean

	Mean fort.				Small fort.	
Polygons	IV.	V.	VI.	VII.	IV.	V.
	fathoms	fathoms	fathoms	fathoms	fathoms	fathoms
Interior ſide	120	130	130	130	110	110
Demigorges	20	25	26	26	20	22
Right-angled flanc	Un-deter-min'd.	24	24	24	Un-deter-min'd.	24
Inclination of the flanc	0	3	3	3	0	3
Second flanc	0	10	13	15	0	0
The right ſally of the orillon	0	1	1	1	0	1
Retreat of the orillon as far as the caſemate	0	1	1	1	0	1
Retreat of the curtin as far as the caſemate	0	0	0	0	0	0
Caſemate	ſquare	ſquare	ſquare	ſquare	ſquare	ſquare

2. The polygons above the heptagon have the ſame dimenſions as the heptagon, excepting with reſpect to the demigorges that undergo the changes of the foregoing rule.

3. The author would not have the ſmall fortification made uſe of beyond the pentagon; yet if one was deſirous to do it, the flanc muſt always be allowed 24 fathoms; and one ſhould begin to enlarge the demigorges from the heptagon upwards, leſt the faces ſhould become too ſhort.

By

By the means of this table one may fortify any polygon whatſoever agreeable to the author's method, excepting the ſquare, for which there is a particular ſtructure that we ſhall be careful not to omit.

Suppoſing a hexagon was given to be fortified, look into the table under the *roman* cypher VI. that ſtands for a hexagon, and you'll find 150 fathoms for the interior ſide *a b* of this polygon, and 28 fathoms for each demigorge; at the extremities of the curtin raiſe the flancs perpendicular thereto, as is ſet down in the table, and give to each 25 fathoms. Having made them at firſt perpendicular, as A B and C D, you muſt afterwards ſomewhat incline them by taking three fathoms from A to E, then join B E, and that will give you the real flanc. By the table you may ſee that the inclination of the flancs is the ſame in all polygons, and that in the ſquare they remain perpendicular upon the curtin. Then take 14 fathoms on each ſide for the ſecond flancs, and from theſe points *c d*, where end the ſecond flancs, draw the lines of defence, which paſſing at the extremities of the right flancs will interſect one another upon the ſemidiameter of the polygon, and will thus determine the faces, and the whole is finiſhed. Fig. 16. Fig. 17. Fig. 16.

For the orillon, take ſeven fathoms upon the flanc D H from D to I, carry two fathoms and a half upon the face of the oppoſite baſtion from the flanked angle thereof, and from the neareſt points draw an indefinite line paſſing at I, take one fathom without the flanc from I to F; this ſpace is called in the table the right ſally of the orillon; from the point F draw F D to the angle of the ſhoulder, and then after having a perpendicular in the middle of that line, and another on the extremity of the face, you'll Fig. 17.

deſcribe the convexity of the orillon from the center O, where theſe perpendiculars interſect each other.

For the caſemate, take upon the indefinite line that you have drawn from the face of the oppoſite baſtion through the point I, one fathom from I to L; and from the points L and H, with the interval L H, deſcribe two arches without, and the point of interſection will be the center to deſcribe the concavity of the low flanc; the part I L is that which is called in the table the retreat of the orillon as far as the caſemate; the high flanc is deſcribed from the ſame center, at the diſtance of ten fathoms from the low one; it is determined towards the face by the indefinite line, but it is made to run in within the place 15 fathoms beyond the retreat of the curtin; this is done by making upon the line T V an equilateral triangle V T P, and from its ſummit P deſcribing the arch T S, thereto to draw a chord T S of 15 fathoms. The retreat of the curtin is found by drawing a line from the angle of the oppoſite ſhoulder through the foot A of the perpendicular flanc A B, till it meets with the high flanc in T.

The ſecond curtin is diſtant ſeven fathoms from the firſt; Fig. 16. the coffer is drawn from one angle of the ſhoulder to the other that is oppoſite to it.

For the half-moon, from every angle of the ſhoulder ſet off *h* and *i* upon the faces at eight fathoms, and having divided the diſtance *h i* into eight parts, you muſt deſcribe with an interval equal to ſeven of thoſe parts, from the points *h* and *i* as centers, two interſecting arches, whoſe point of interſection will give you the flanked angle of the half-moon; its faces muſt be drawn to *h* and *i*; its foſſè is allowed 12 fathoms, and is defended by retired batteries upon the faces of the baſtions, ſomething like thoſe

in

in M. *Blondel*'s fortification, excepting that inſtead of making Z X in a direction with the counterſcarp of the half-moon. This author draws it towards the faces, within three or four fathoms of the flanked angle, which is much better, becauſe by theſe means there is always a cannon of theſe batteries that lies quite concealed, nor can the enemy ever diſcover it. It was forgot to be mentioned, that the foſsè of the place is 16 fathoms at the angles of the baſtions, and is drawn towards the angles of the ſhoulder. Fig. 17.

The little reduit is deſcribed by retrenching from each ſide of the low curtin ten fathoms for the great and mean fortifications, and five fathoms for the ſmall ſort, and with the interval *s r*, from the points *s r* as center, making an interſection whoſe points will give you the flanked angle of the reduit; its faces muſt be drawn to the points *s*, *r*.

The counter-guards are 16 fathoms thick. At the extremity of the faces the author makes a ſort of a flanc, whoſe dimenſion and form we have given in a ſeparate figure, which is ſufficient to render the ſtructure thereof intelligible; the line A B is drawn within four fathoms of the flanked angle of the half-moon.

The covert-way and glacis are traced out as uſual; and was it deſired to have an avant-foſsè, the author would not have it done according to the common method, becauſe it may ſerve as an intrenchment to the enemy, could he but drain the water; but he propoſes to continue the firſt glacis from the parapet A of the covert-way to the foot B of the counterſcarp of the ſecond glacis; this is certainly much ſafer and preferable. Fig. 18.

The polygons of the great fortification from the heptagon upward, and thoſe of the middle ſort from the octogon, have their flanked angles, right angles. The author forms this angle by joining the extremities of the flancs by a

right line, upon which he deſcribes a ſemicircle, and from the middle of its circumference he draws the faces to the extremities of the flancs; theſe faces being prolonged, afford a ſecond flanc upon the curtin, and therefore this flanc in the table is ſet down, *undetermined*, becauſe inſtead of, as in other polygons, this flanc fixing the angle of the baſtion, in theſe laſt mentioned it is itſelf determined by the flanked angle.

The retrenchments in the baſtion are made as thoſe in the figure, whereby, in caſe of neceſſity, you may only throw up the earth that lies betwixt the lines N Z, M Y,
Fig. 17. doing the ſame on the other face, and you cut off all communication with the breach.

For the ſtructure of the ſquare, give to the demigorges the number of fathoms ſet down in the table, and raiſe at both extremities of the curtin indefinite perpendiculars
Fig. 19. thereto; this done, to have the flanked angle A, join B C, upon which make the equilateral triangle B A C; the angle A will be the flanked angle, and the ſides B A, A C, will be the lines of defence, and ſhall determine the faces and flanc, which in the table are called *undetermined*, becauſe the author does not determine them before he draws the lines of defence, as in other polygons.

In all ſquares, and in the pentagon of the ſmall fortification, the gorge of the baſtion is not large enough to allow of thoſe retrenchments that are made in greater polygons; therefore the author raiſes a little baſtion, whoſe
Fig. 20. face is defended in a razant line by the oppoſite flank; but as it is requiſite for that purpoſe that the parts E F of the caſemate and high flanc ſhould not be admitted, and that the lower curtin, was it made the ſame as in other polygons, would then be without any defence, he places this one in the place where the great one ſhould be, and retires the great curtin within the town.

The

The ramparts are eight fathoms thick including the parapet, which is allowed three fathoms for the curtin and faces, for the lower flancs and all the out-works, and 20 feet for the high flancs. The terre-plein of the baſtion is raiſed three fathoms above the horizontal line, and that of the curtin only two fathoms. The lower curtin is upon a level with the covert-way, and the foſsè is two fathoms deep. The lower flanc is raiſed one fathom above the horizontal line, and of conſequence is ſix feet higher than the lower curtin; its terre-plein is ſeparated from the high flanc by a foſsè three fathoms broad, to leſſen, in ſome meaſure, the terrible effects of bombs. There is a little ſpace left betwixt the lower flanc and the retreat of the curtin, to ſerve as a deſcent into the lower curtin. The outworks are three feet lower than the high curtin; the parapet of the coffer is raiſed four feet above the bottom of the foſsè.

The high curtin, the retired batteries upon the faces, and the reduit are not lined with brick-work or maſonry, which diminiſhes greatly the expences.

Remarks on the firſt ſyſtem of an anonymous author.

It muſt be allowed, that the invention of this ſyſtem is very judicious; all the pieces therein are well flanked, and the defences are neither too oblique or too open; the flancs are of a reaſonable ſize, and have even the advantage of greatly increaſing their fire by being prolonged within the place; hereby they may be looked upon as razant. The caſemates are rendered as uſeful as can be expected, without being ſo liable to accidents from the enemy's bombs, becauſe of the foſsè that ſeparates them from the high flancs; and if the author makes a fauſſe-braye 'tis only before the curtin, which is ſeldom expoſed to the enemies attacks; and then he

he does not deſign it ſo much with a view to ſtrengthen the place, as to ſave the ſums that it would coſt to line the high curtins on every ſide of the polygon.

With all theſe advantages, there are ſome eſſential errors in this ſyſtem that ought neceſſarily to be corrected before ever it is brought into practice. The baſtions are raiſed too high above the outworks, which are at leaſt 15 feet lower, this expoſes them too much to the enemy's fire. The caſemates are alſo too high with reſpect to the high flancs, which are only two fathoms above them. The retired batteries in the faces facilitate greatly the breach. Laſtly, the author had done much better if he had lengthen'd his flancs outwards, making his defence razant, than to have prolonged them inwards, whereby their fire becomes very inconvenient to a great part of the curtin: but he owns himſelf, that in this he did not follow his own inclination, and was it not to avoid the augmentation of expences, to which many people pay too great a regard at very unſeaſonable junctures, he ſhould prefer the two other plans that are at the end of his book, whoſe ſtructures will immediately follow. We have ſaid nothing about the difference of his caſemates, which he makes either flat or round, according as he wants to gain ground; becauſe by the table one may ſee in what polygons he makes uſe of them. We ſhall only add, that he is deſirous of diſpoſing the ſtreets of a new place after the manner they are drawn out in the figure, to have the houſes repreſent either a tenaille or horn-work before each baſtion, together with a half-moon, that they may ſerve as intrenchments; but it is not probable that a whole town ſhould undergo the inconveniencies of ſuch a diſpoſition for an advantage in the main ſo inconſiderable, and that one ſeldom cares to depend upon.

The

The ſecond ſyſtem of an anonymous author.

THE author having propoſed this and the following ſyſtem as mere projects, has only given us the ſtructure of them for an octogon, even without a ſufficient explanation; but it would be eaſy to apply them to all ſorts of polygons by following his idea; and for the ſtructure, we ſhall here lay it down as the Abbot * *Deidier* has imagined it, and which agrees very well with what the author himſelf ſays thereof.

Draw the line *a b* indefinite towards *b*, at the point *a* make the angle *b a o* 67 degrees and an half, which is half of the angle of the polygon in an octogon; make alſo at Fig. 21. the ſame point *a* the diminiſhed angle *b a d* of 32 degrees and a half, ſo that the half-angle of the baſtion may be 35 degrees, and of conſequence the whole flanked angle of 70 degrees; give to the line of defence *a d* 150 fathoms, and to the face *a c* 52 fathoms; from the point *d* draw an indefinite line parallel to *a b*, and fixing your compaſſes at the extremity *c* of the face, deſcribe an arch with an interval of 58 fathoms, until it interſects the laſt drawn line at the point *n*, which join to *c* by a right line that will be the flanc, and conſequently will be 58 fathoms long. Then in the middle of the curtin *n d* erect a perpendicular until it cuts the line of defence at *b*, through which point, and through the point *n*, you may draw another line of defence *n b*, to which give from *n* to *b* 150 fathoms; upon this line take the face for the adjacent baſtion, and from the extremity of the face draw the flanc to the extremity of the curtin. After this, to find the center of the polygon, let fall the perpendicular from the

* Author of *Le parfait Ingenieur françois.*

the middle of the curtin until it interſects the ſemidiameter *a o* at the point *o*, which will be the center, from which you may deſcribe a circle, and upon whoſe circumference you may meaſure the ſide *a b* eight times.

After this, it will not be difficult to make the ſame ſtructure for the other ſides of the polygon. All that is requiſite is only to draw from the center *o* a perpendicular line *o i* upon the middle of thoſe ſides, and take *o s* equal to *o b*, and then draw through *s* from each angle of the polygon the lines of defence, to each of which give 150 fathoms, and finiſh the reſt according to the other meaſures above given.

The flanc *c n* muſt be divided into two parts, the firſt of which, *t n*, is 25 fathoms, and the ſecond, *c t*, is 33 fathoms; from the foot *d* of the oppoſite flanc there is drawn a line *d t*, which interſects the ſemidiameter of the polygon, and forms one face of the interior baſtion. The caſemates and high flancs of this baſtion are circular, but thoſe of the exterior baſtion are in a right line; there is always a foſsè three fathoms broad betwixt the high flancs and low ones. Before the caſemates of the interior baſtion there is made a ſmall convex flanc, which only ſerves for muſquetry; it is one fathom lower than the caſemate.

The foſsè is deſcribed, by firſt drawing a line from the flanked angle *a* to the oppoſite angle of the ſhoulder, and afterwards drawing a parallel line to the face *a c* at the diſtance of 16 fathoms from the ſaid face, until it interſects the other at *u*; the depth of this foſsè is four fathoms from the angle of the ſhoulder *t* of the interior baſtion unto the counterſcarp, and goes off in a talus towards the curtin, where its depth is reduced to one fathom. There is a caponiere that runs from one angle of the ſhoulder of the interior baſtion to that of the other. The faces of the

the exterior baſtions are raiſed two fathoms above the horizontal line, and are conſequently ſix fathoms from the bottom of the foſsè. The interior baſtion is raiſed three fathoms above the horizon. The low flanc of the exterior baſtion is raiſed two fathoms from the bottom of the foſsè, but the high flanc is raiſed four fathoms. The reſt of the baſtions betwixt the high flancs is upon a level with the low flanc; ſo that, in caſe of neceſſity, one might cut off the high flanc, which is only four fathoms and a half thick, and thereby intirely ſeparate the interior baſtion. The work that runs along the counterſcarp, and that the author calls a falſe-braye, has its flancs 25 fathoms long, and its line of defence ought never to exceed 150 fathoms. The foſsè of this work ought to be 12 fathoms before its faces. The three half-moons, and what elſe remains of this ſtructure, is eaſily conceived by caſting an eye upon the plan.

Remarks on the ſecond ſyſtem of an anonymous author.

This fortification conſidered in itſelf, and deprived of ſuch circumſtances which render it almoſt impracticable, would be excellent, if the author, inſtead of digging ſo deep a foſsè and lowering his out-works, had, on the contrary, raiſed them after M. *de Vauban*'s example; ſo that the body of the place, of which the out-works ſtand in no need of their defence, had been almoſt intirely covered. Hereby the enemy, after having taken thoſe works with much coſt and pains, (for their reſiſtance would certainly not be inferior to that of the ſtrongeſt places,) would ſee himſelf obliged to begin, at freſh coſt and trouble, another ſiege ſtill more troubleſome, not being able to place himſelf elſewhere than on a heap of ruins, enfiladed on all

ſides, and where he could retrench himſelf but with the utmoſt difficulty.

However, when one comes to conſider the exceſſive expences of this fortification, and the number of ſoldiers it requires to man its works, eſpecially if one had to deal with mutinous and diſcontented inhabitants, who care little what prince they obey provided their houſes are not deſtroyed by bombs, one ſhould ſoon ſee that two or three places thus fortified would intirely drain a prince's coffers, and depopulate his dominions. It is true, a prince ought to ſpare nothing on ſuch-like occaſions, becauſe the loſs of his ſtrong places would ſtill be a greater loſs; but prudence ought to direct him, and theſe expences ought not to render him incapable of keeping a good army in the field, by obliging him to make uſe of the greateſt number of his troops for garriſons.

The ſecret of fortification does not then conſiſt in multiplying the works; otherwiſe there need only be made great number of out-works one before the other, and one ſtronger than the other; but in diſpoſing them in ſuch a manner that one may be able to make a vigorous defence with a ſmall number of troops, which may not conſiderably diminiſh thoſe that ought to be in the field to make head againſt the enemy; and this is found in M. *de Vauban's* ſyſtems, much better than in all others.

The third ſyſtem of an anonymous author.

THIS third ſyſtem differs from the ſecond with reſpect to the body of the place, by having the faces of the baſtions longer, and the flancs leſs inclined. For its ſtructure, make the ſame angles as in the laſt, and after having given

given 150 fathoms for the line of defence, and drawn the indefinite line B C, draw another indefinite line S P within the place, and parallel to B C at ſix fathoms diſtance; afterwards take 56 fathoms upon the line of defence from A to D for the face of the baſtion; take 58 fathoms, and fixing one foot of your compaſſes in D, with the other deſcribe an arch that will interſect the line S P at S, to which point draw your flanc S D; this flanc will interſect the indefinite line C B at C; divide C B equally in two L, upon which raiſe the perpendicular L H E that will interſect the line of defence at H, and fall upon the middle E of the exterior ſide of the polygon; from the point C, through H, draw the other line of defence, and finiſh what remains as in the foregoing ſyſtem. Fig. 22.

The great half-moon is deſcribed as it is in the firſt method; the ſecond has its faces drawn to the orillon of the exterior baſtion; and the faces of the reduit are drawn to the orillon of the interior baſtion. Fig. 23.

The flanked angle of the counter-guard is 70 fathoms diſtant from the flanked angle of the exterior baſtion; the faces are drawn to the counterſcarp of the half-moon, within 30 fathoms of the flanked angle. This work has no foſsè.

Remarks on the third ſyſtem of an anonymous author.

Although this fortification ſeems to be leſs compoſed than that of the laſt-mentioned ſyſtem; nevertheleſs, if it is nearly examined, it will be found to be almoſt as expenſive, becauſe of the double counter-guards; and it requires much about an equal garriſon, if one would prevent ſurpriſes, which may very eaſily happen to thoſe

works, becauſe there is no foſsè betwixt them and the covert-way. Moreover, the large ſize of theſe counter-guards, to which add their continuity with the covert-way, offer a vaſt ſpace to the enemy, which he can approach without much trouble, and retrench himſelf therein, to the great detriment of the place, having firſt ruined the defences of the half-moons.

It is alſo improper that the author, in this ſyſtem, at once preſents to the enemy's view all the ſtrong parts of a place like a ſort of amphitheatre, whoſe higheſt pieces are even too elevated; this great diſplay only ſerves to warn the beſiegers to redouble their batteries, and their violence nothing can withſtand; whereas by having ſome hidden reſources, the beſiegers meet with much more hindrance and trouble. The interior baſtions, for example, would be excellent for ſuch purpoſes, had he made them lower, and had he covered them more by prolonging the orillon of the exterior baſtions; for then the faces of the interior baſtion could not be battered but from the rampart of the exterior baſtion, which is of no great extent, and where the enemy could bring up cannon but with extreme toil and fatigue, becauſe of the great depth of the foſsè.

We have forgot to mention, that inſtead of a terre-plein for the lower curtin, the author propoſes to make a canal full of water, where ſhould be placed batteries upon boats, covered with pent-houſes to prevent their being damaged by bombs; this expedient is new and ingenious. But the author is not quite ſo much in the right when he adds, that the water of this canal might ſerve to overflow the foſsè after the enemy had mounted the breach; for it is not eaſily to be imagined that a foſsè of four fathoms deep, and 16 fathoms wide before the faces of the

the baſtion, can be overflowed by ſo ſmall a quantity of water.

The TWO SYSTEMS *of the Chevalier St.* JULIEN.

The ſyſtem of the Chevalier St. Julien *for great places.*

THE Chevalier St. *Julien* has invented a method to fortify great places, which coſt moſt to defend, whereby he pretends not only that the expence is reduced, this we'll grant him, but alſo that the ſtrength of the place is greatly augmented; this we ſhall examine, after having laid down the ſtructure.

Suppoſe then that we had an octogon to fortify according to this ſyſtem; give to the exterior ſide *a b* 240 fathoms; divide this line equally in two at the point *c*, and make the perpendicular *c i* 24 fathoms, which is equal to the tenth part of the exterior ſide; draw through the point *i* the lines of defence *a i l*, *b i h*, and make *i l*, *i h*, each of them equal to 70 fathoms; join *h l* by a right line, which will be the curtin, and from its middle *o* draw the lines of defence razant *o a*, *o b*, thereon to take 48 fathoms for each face, equal to the fifth part of the exterior ſide; then draw your flancs from each extremity of the curtin. Theſe meaſures ſerve for all ſorts of polygons. Fig. 24.

For the orillon, take two fifths of the flanc, and finiſh the reſt after M. *de Vauban*'s manner. The foſsè, whoſe counterſcarp is parallel to the faces of the baſtion, is 20 fathoms broad; and as in this ſyſtem the lines of defence for the muſquet is taken from the middle of the curtin, the author places in the foſsè, from the middle of the curtin to the gorge of the half-moon, a covered caponiere ſeven feet high and ten fathoms broad, wherein he places

cannon,

cannon to flank the faces, and over them he makes a gallery for the muſquetry, and to ſerve as a paſſage to the ravelin.

The half-moon or ravelin has 45 fathoms for the capital; its faces are drawn within 15 fathoms of each extremity of the curtin; its foſsè is 10 fathoms; the counter-guard is allowed 35 fathoms from *p* to *q*; its faces are parallel to thoſe of the half-moon, and its foſsè is 12 fathoms wide.

The covert-way is five fathoms broad; the demigorges of the places of arms are 15 fathoms, and their faces 20 fathoms; they are covered by traverſes on each ſide, and in the middle are made redoubts, wherein are placed cannon and muſquetry on proper occaſions; the glacis is 30 or 40 fathoms.

The rampart is 12 fathoms thick, including the parapet which is five fathoms, that it may reſiſt the better. The height of the rampart above the horizon is but two fathoms, and the out-works are only two or three feet lower; this the author has obſerved, that the enemy's batteries might have leſs hold, by burying as it were the works, which he covers by traverſes at certain diſtances, to prevent the enfilade. In ſeveral places he raiſes cavaliers for barbet batteries, eſpecially at the gorge of every baſtion, where the cavalier has two different batteries, the one raiſed higher than the parapet of the place, and the other on a level with the top of the rampart, and vaulted bomb-proof. Laſtly, to render the flancs of the rampart and caſemates more ſolid, he has contrived a new ſort of
Fig. 25. merlons and embrazures, which he deſcribes in circular form; the embrazures are allowed one fathom and a half, and the merlons two fathoms.

Remarks

Remarks on the Chevalier St. Julien's *ſyſtem for great places.*

Although there are ſome excellent things in this ſyſtem, ſuch as the cavaliers of the gorge, that in a manner ſeparates the baſtions from the body of the place, and puts the beſieged in a condition to defend themſelves the longer after the breach is made; yet the faces are too obliquely flanked by the caponiere that runs from the middle of the curtin to the gorge of the half-moon, which caponiere can be intirely ruined by two or three of the enemy's bombs; the flancs alſo are not ſufficiently covered, ſince the enemy, having deſtroyed the parapets of the half-moon and of the counter-guard, diſcovers thoſe of the flanc upon a very large front.

The merlons of the flancs cut in a circular form are certainly more ſolid than they would be otherwiſe; but it is a queſtion whether they are ſo convenient for traverſing the cannon.

The ſyſtem of the Chevalier St. Julien *for ſmall places.*

THE intention of the author in the foregoing ſyſtem was, as we have already obſerved, to reduce conſiderably the prodigious expences which are required to fortify a large city; but as there are ſeveral ſmall places which are of great importance, and may be fortified at leſs expence, he has imagined for theſe a new ſyſtem, which is preferable to his other ſyſtem, but is not entirely free from defects.

Suppoſe an hexagon was given to be fortified, give 180 fathoms to the exterior ſide *a b*, and make *c d* the perpendicular equal to a fourth part of that ſide, which is 45 fathoms; Fig. 26.

fathoms; then draw the lines of defence indefinite, and make *a l* and *b i* 120 fathoms; give 60 fathoms to the faces *a s*, *b r*, and carry 30 fathoms from *d* to *o*, from *d* to *t*, the line *o t* will be the curtin of the place, and the line *i l* will be the curtin of the tenaillon; draw the lines *t r*, *o s*, and through the angle of the ſhoulder draw *r p*, *s q*, parallel to the exterior ſide. Within make a foſsè eight fathoms wide, and hereby you'll have the faces *u x* of the baſtion, and you will alſo determine the right lined flanc *x t*, which you may make concave, and thereto add an orillon according to M. *de Vauban*'s manner. Then draw the flancs of the tenaillons parallel to thoſe of the place, until they meet the prolonged faces of the exterior or avant baſtion.

The foſsè of the place is 16 fathoms wide; the capital of the exterior half-moon is 70 fathoms; its faces are drawn to the points *z n*, which are 20 fathoms diſtant from the extremities *r s* of the faces of the avant-baſtion; its foſsè is 12 fathoms.

The capital of the interior half-moon is 45 fathoms; its faces are parallel to thoſe of the exterior half-moon; its foſsè is 10 fathoms wide, and its gorge is rounded off, ſo that one may ſee from *u* to *a* without any interruption; this the author does becauſe he deſigns that a battery might be placed in the dry foſsè *u p* to gall the enemy, after he had made a breach at the flanked angle *a* of the exterior baſtion.

We have forgot to make little flancs to the half-moons, as the author has done.

The covert-way is as uſual, and the glacis ought to be 35 to 40 fathoms.

Remarks

Remarks on the Chevalier St. Julien's *ſyſtem for ſmall places.*

According to this ſyſtem, the flancs have a good defence that comes very near to a direct one, and yet they are not too much uncovered. The faces of the interior baſtion are quite hidden to the beſiegers batteries; the breach is battered in the rear from the battery of the dry foſsè of the oppoſite baſtion, againſt which the enemy cannot bring any cannon to bear. Laſtly, the tenaillon is capable of affording a great defence, becauſe its flancs are very long; but it muſt alſo be obſerved, that the flanked angle of the avant-baſtion is too acute, and that of the inner one too obtuſe; this facilitates greatly the breach, whereon the enemy can at any time make a lodgment, notwithſtanding the battery of the dry foſsè, becauſe he can deſtroy it by bombs, though he cannot make uſe of cannon againſt it. To this add, that as ſoon as this battery is ruined, the faces of the interior baſtion remain quite defenceleſs.

The ſyſtem of Donato Roſſetti, *commonly intitled* Fortificazione a roveſcio.

Donato Roſſetti, a canon of *Leghorn*, profeſſor of mathematics in the academy of *Piemont*, and mathematician to the Duke of *Savoy*, is the author of the following ſyſtem, which he publiſhed in *Italian* Dialogues in 1678. His book is very ingenious, and contains ſuch judicious obſervations concerning fortifications, eſpecially conſidering the time it was wrote in, that it is ſurpriſing it has not been more univerſally taken notice of than hitherto it has been, ſince ſeveral others, certainly much inferior to this, have been too favourably received.

The author intitles his ſyſtem, *Fortificazione a roveſcio*, which in our language ſignifies, that it is deſcribed in a manner quite contrary to that of other fortifications; not only becauſe the re-entering angle of the counterſcarp is juſt before the flanked angle, which is contrary to all other ſyſtems; but alſo becauſe the author imagines that it muſt be attacked in a contrary manner to that wherein others are attacked.

Fig. 27. For the ſtructure, ſuppoſe an octogon, whoſe interior ſide A B is taken for 108 fathoms; after having prolonged the ſemi-diameters indefinitely, and raiſed indefinite perpendiculars in the middle of the ſaid interior ſide A B, divide it into ſix equal parts, and take one for each demigorge, and one for each flanc, that muſt be drawn perpendicular upon the curtin. The lines of defence are always razant, and determine the faces; at each extremity of the curtin take 12 fathoms from C to E and from D to F, and upon E and F raiſe perpendiculars, which, interſecting the lines of defence, give the low flancs with their faces.

Take upon the extremity of the ſuperior faces from the angle of the ſhoulder three fathoms, and fixing one foot of your compaſſes at S, and the other at T, deſcribe an interſection, at whoſe point you will have the flanked angle of the half-moon; its faces are drawn from thence to the points S and T, and are 30 fathoms each. This being performed on every ſide of the polygon, draw from the extremity R of the face of one of the half-moons the line R Q P, which paſſing at Q, the flanked angle of the other is determined at P by the interſection of the line of defence prolonged from the remoteſt face of the oppoſite baſtion; then take ſix fathoms upon the curtin from E to V, and having drawn the exterior ſide of the polygon,

polygon, draw alſo V P, which cuts the exterior ſide at N; join N with the extremity of the face of the half-moon, and this line ſhall be its flanc. For the remaining flancs, you need only ſet off the diſtance from N to the perpendicular in the middle, on each ſide of all theſe perpendiculars, and you will have the points, whereto from the extremity of the faces you are to draw the flancs. From the point P draw the line P M to the angle of the ſhoulder of the oppoſite half-moon, and prolong it on the other ſide towards X, at which point it will interſect the indefinite perpendicular raiſed upon the middle of the curtin, ſo that by carrying the diſtance Z H from the flanked angle of the baſtion outwards upon every prolonged ſemi-diameter of the polygon, and the diſtance X Q upon all the indefinite perpendiculars from the flanked angles of the half-moons, and afterwards joining the outward extremities of theſe diſtances, you will deſcribe the whole extent of the counterſcarp round the place.

The covert-way is five fathoms broad; but the breadth of the glacis at the re-entering angles is equal to the length of the lower flanc, and at the ſaillant-angles it is doubled; this the author did contrive that the face of the baſtion might raze the glacis on all ſides. Sometimes he prolongs this glacis until it comes to be ſix feet lower than the horizontal line, Fig. 28. the part whereof I L, that lies below the horizon, he calls a ſecond glacis, to which he adds a ſecond covert-way L H.

The height of the higher faces and flancs, their parapets incluſive, is ſix fathoms above the horizontal line; the height of the lower flancs and faces, and of the curtin, is but three fathoms from the ſaid line. The breadth of the foſsè is divided into three different parts, which the author names the *dry foſsè*, the *fordable foſsè*, and the *deep foſsè*.

The counterſcarp is three fathoms lower than the horizontal line, upon which take 18 fathoms from A to B; and having divided the line AB equally into two at C, Fig. 28. let fall the perpendiculars BE, CF, the firſt of which, BE, is determined by the ſurface of the water; the ſecond, CF, is four or five feet under water; and then draw the line OEFG, the part thereof OE is allowed for the dry foſsè, the part EF is for the fordable foſsè, and the part FG is for the deep foſsè. It does not ſignify whether the line OEFG is a right line or not, the level of the water is to regulate this. The foſsè at the foot of the counterſcarp muſt be dug deep enough to afford eight or nine feet of water at leaſt.

The covert-way is raiſed one fathom above the horizontal line, and the height of the half-moons above the bottom of the foſsè is about four or five fathoms and a half. The author joins them to the higher faces of the baſtions by a wall that he calls *chemin des rondes*, becauſe one may come along the top of this wall to go the rounds in the half-moons. By this he reckons to diminiſh the number of centinels, which he only places at the flanked angles, and to allow a place before the curtin to lodge the auxiliary troops which could not be billetted in the town; beſides, deſerters could not ſo eaſily make off; but in caſe of a ſiege he would have theſe walls demoliſhed in thoſe fronts that ſhould be attacked, that they might not hinder the defence of the lower flancs.

In the dry foſsè he adds two falſe-brayes, whoſe profils Fig. 29. are repreſented in the figure; the exterior one that is next to the fordable foſsè, is dug ſix feet deep in the ground, and is three fathoms broad; the other, that is upon the ſame level as the dry foſsè, is at three fathoms diſtance from the point of the baſtion, and is covered by a parapet made

made with the earth dug out of the exterior one. Laſtly, the author propoſes intrenchments in the half-moons, ſuch as is deſcribed in the figure 27, at the half-moon Y; but this ſhould be done only when occaſion required it, and the earth that is taken from the flancs ſerves to make the interior faces.

His ſtructure varies in other polygons with reſpect to the different dimenſions, as may be ſeen in the table we ſhall hereafter inſert for the ſatisfaction of the curious, and in the manner in which he deſcribes the ſquare, which ſhall be ſoon explained; but we will firſt lay down the peculiar names the author makes uſe of in his treatiſe.

The line C E is called the *wing of the baſtion*; the height of its rampart is double that of the curtin.

The line E V is termed the *wing of the curtin*, becauſe it diſcovers the point of the aggreſſor.

The line R Q is called the *fixed line*, becauſe it is drawn always in the ſame manner in every polygon whatſoever excepting the ſquare, wherein it cannot poſſibly be drawn ſo, as may be ſeen by the figure of that polygon.

The prolongation P Q of the aforeſaid line is called the *directory line*; it is not always terminated as in this example, by the prolongation of the line of defence interſecting it, becauſe ſometimes the foſsè would become too narrow before the flanked angles of the half-moons; but the author fixes it as is moſt convenient; this is ſhewn in the table.

The line P H K is called the *variable line*, becauſe it does not at all times coincide with the line of defence, but ſometimes terminates at the angle of the flanc, ſometimes lower towards the curtin, and ſometimes higher according to the different polygons.

The

The line P V is called the *third concurrent*, becauſe it interſects both the lines P R and P K.

The point P is called the *point of the aggreſſor*, becauſe the author pretends that it is at this point that the beſieger muſt make his bridge for the paſſage of the foſsè.

Laſtly, the line M Z P is called the *terminating line*, becauſe thereby you deſcribe the counterſcarp round the place.

We have omitted to obſerve, that to trace in the ichnographical plan the line that bounds the interior extremity of the wet foſsè, you muſt divide the diſtance Z H into two equal parts, and then from the point P raiſe the perpendicular P I upon the line P K, which perpendicular muſt be made equal to the lower flanc; this done, what remains may eaſily be finiſhed by mere inſpection of the figure. It is to be obſerved likewiſe, that the author rounds off half of the higher flanc towards the curtin, and draws that part of the lower flanc that is cut by the line of defence, towards the extremity V of the wing of the curtin.

In the ſquare, the greateſt number of theſe lines cannot be drawn after the ſame manner, becauſe the half-moons are intirely hidden one from the other; therefore here follows the proper ſtructure for that polygon.

The interior ſide is allowed 108 fathoms, each demi-gorge is 15 fathoms, the higher flancs 15 fathoms alſo,
Fig. 30. the lines of defence are razant; the wing of the baſtion is 15 fathoms, the wing of the curtin ſix fathoms; the flanked angle of the half-moon is found by the ſame means as already given; each of its faces is 30 fathoms. Then from a point at the diſtance of three fathoms from the flanked angle of the baſtion, draw the fixed line A B, which being prolonged 22 fathoms from B to C, you have the

the line B C for your directory line. The terminating line is found by prolonging the ſemidiameter of the polygon, and carrying from E to F 21 fathoms, and joining F C you may eaſily finiſh the reſt as is above explained, and by viewing attentively the figure. The variable line ought not to occaſion the leaſt trouble, for the author only makes uſe of it to ſhew the quantity of fire the beſieger is expoſed to in different polygons. Here follows the table.

Polygons	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Interior ſide	108	96	102	105	108	108	108	108	108
Demigorge	15	12	12	15	18	18	18	18	18
Wing of the baſtion	15	12	15	13 1/4	12	12	12	12	12
Wing of the curtin	6	6	6	6	6	6	6	6	6
Face of the half-moon	30	24	27	28 1/4	30	30	30	30	30
The directory line	22 1/4	22 1/4	22 1/4	26 1/2	25 1/2	25	24	23	22 1/4

Remarks on the ſyſtem of Donato Roſſetti, *commonly called* Fortificazione a roveſcio.

Nothing ſhews more the genius and capacity of this author, than the plainneſs and ſimplicity of his ſyſtem, that neither requires great expences, or a numerous garriſon; and

and yet oppoſes to the enemy an equal, if not a ſuperior fire, to many other ſyſtems much more compoſed. The invention of his foſsès, wherein are found all at once the advantages of water, and of dry foſsès, without any more coſt for their ſtructure than for the ordinary manner of foſsès; the art whereby he raiſes his walls upon the horizontal line, ſo that the enemy cannot perceive the foot thereof but when he is placed upon the counterſcarp; the hollow half-moons, wherein it is impoſſible for the beſiegers to lodge themſelves without being ſorely galled from the place; the falſe brays, which are not enfiladed, and exceedingly well placed to defend the paſſage of the foſsè; laſtly, the lines of defence razant, which he makes uſe of notwithſtanding the univerſal prejudice and received notion of the *Italians* in favour of the ſecond flanc, prove the excellency of his judgment. His book contains ſeveral other uſeful and good things relating to this art, which however we ſhall omit, to ſupply their place with others that we judge ſtill more neceſſary to our preſent purpoſe.

The author, it ſeems, makes two ſuppoſitions, which, if found to be falſe, will diminiſh by the half the force of his ſyſtem. The firſt is, that the enemy being come as far as P, which he calls the point of the aggreſſor, muſt ſtill be expoſed to all the fire of both the high and low face of the wings of the baſtion and curtin, of the face of a half-moon, of the flanc of another, and of the two flancs of the baſtion. The ſecond ſuppoſition is, that the enemy muſt chooſe that point to lodge himſelf upon the counterſcarp preferably to any other. We need not ſtand to refute the firſt, which of itſelf is evidently falſe, ſince every body knows that the beſiegers ſeldom advance as far as the counterſcarp but after that they have ſilenced all the batteries of the beſieged which could be diſcovered from

from the furtheſt off; and it muſt be obſerved, that nothing in this ſyſtem prevents the former to be able to deſtroy from the field the high faces of the baſtions, thoſe of the half-moons, and the wings of the baſtion.

His ſecond ſuppoſition ſeems more probable, becauſe indeed you can batter the flancs of the baſtion K, but from this point, and you are obliged, in the attacks of this ſyſtem, before the paſſage of the foſsè is attempted to mount the breach at H, to raiſe another battery at the oppoſite point to batter the baſtion B and the flanc N of the half-moon, both which defend the paſſage of the foſsè; but allowing theſe ſuppoſitions, each of theſe batteries muſt withſtand, at the ſame time, all the fire of the flancs of the baſtion and of the oppoſite half-moon. There is no reaſon why the enemy ſhould not make uſe of the faces of the place of arms of the re-entering angle, and by cutting into the glacis to make proper epaulements, fix two croſs-batteries that would batter the flancs of the half-moons; after theſe were deſtroyed, the batteries might then be removed to the points of the aggreſſor; the glacis could at once be cut away at theſe points, and this would be better; ſo that the beſieger might be covered from the flancs of the baſtion, and after having battered the flancs of the half-moons in enfilade, he might then direct his batteries againſt the flancs of the place. It is certainly no inconſiderable advantage in this ſyſtem to oppoſe conſtantly to the paſſage of the foſsè the flancs of two baſtions; but certainly this ſame advantage is greatly diminiſhed by a great number of other defects, moſt of them inevitable in the ſtructure of this ſyſtem. The angles of the half-moons are too acute, and thoſe of the baſtions too obtuſe; this facilitates the breach, as we have already obſerved elſewhere. The perpendicular flancs occaſion the

embraſures to be made very oblique, which diminiſh very much the ſtrength of the merlons. The lower flancs are not deep enough in proportion to the higher ones, and both are very much expoſed to be enfiladed, if the parapet of the faces that covers them is overthrown; but this might have been prevented if the author had applied an orillon. Laſtly, the walls raiſed upon the horizontal line are very convenient for the miner, who can eaſily make his way under them, eſpecially if he can ſlip into the firſt falſe bray.

The ſyſtem of Scheiteer *the* German.

COlonel *J. B. Scheiteer*, a *German*, is the author of this ſyſtem. He eſtabliſhes three ſorts of fortification, the *great*, the *mean*, and the *ſmall* ſort. The exterior ſide of the polygon for the great ſort is 200 fathoms, the middle ſort is allowed 180, and the ſmall ſort is 160. The line of defence in the firſt is 140 fathoms long, in the middle ſort 130, and in the ſmall 120 fathoms. This line is always razant. All the other lines are fixed at the ſame length for all polygons, whoſe ſtructure chiefly depends upon the knowledge of the exterior ſide, of the capital, or of the flanked angle, the reſt being eaſily finiſhed, as ſhall be ſhewn after we have laid down the following table, wherein are marked the flanked angles and capitals which muſt be given to each different polygon of theſe three ſorts of fortification.

Table

Table of the capitals and flanked angles.

Polygons	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
The flanked angles in the 3 ſorts of fortif.	degrees 64	76	84	90	95	97	99	101	103
Capital for the great ſort	fathoms 46	49	51	52	53	54½	56½	58	59
Capital for the mean ſort	42	44½	46½	48½	50	51	52½	54	55
Capital for the ſmall ſort	39	41½	42½	45	46	47½	48½	50	50½

The ſtructure may be begun either by the flanked angle or the capital. We ſhall here begin it by the capital, afterwards we ſhall exhibit the manner of doing it by the flanked angle.

Let us ſuppoſe an octogon was given to be fortified, whoſe exterior ſide A B is allowed 200 fathoms for the great fortification, as in this example. Take upon the ſemi-diameters the capitals A C, B D, 53 fathoms each, as is ſet down in the table, and draw the Interior ſide C D; then take your compaſſes, and fixing one foot at the flanked angle A, with an interval equal to 140 fathoms, deſcribe the interſection upon the interior ſide at E; in the ſame manner, from the flanked angle B, make the interſection at F; then join A E, B F, and you will have the two lines of defence; raiſe upon the extremity of theſe lines the perpendiculars E L, F I, for the flancs, which will alſo determine the faces of the counter-guard at thoſe points where they interſect the oppoſite lines of defence. Fig. 31.

Prolong the lines of defence towards the capitals, and make EH, FP, each 16 fathoms long, and having divided them equally in two, draw the higher flancs of the counter-guards parallel to the lower flancs, as in the figure; repeat this on every ſide of the polygon, and then taking the interval PQ with your compaſſes, deſcribe an interſection upon the capital at N, and having drawn the lines PN, QN, you will hereby have finiſhed the counter-guard. At the diſtance of 18 fathoms within the counter-guard, towards the body of the place, deſcribe the foſsè parallel to the counterſcarp of the place, and you will form the redans R, S, T. The author moreover fortifies the ſaillant angle of the eſcarp of the foſsè towards the middle of the curtin, betwixt the two counter-guards, with a baſtion deſcribed in the following manner.

From the point 3, where the lines of defence interſect each other, let fall the perpendicular 3, 4, upon the interior ſide, and make 4, 5, and 4, 6, each equal to 4, 3; join 3, 5, and 3, 6, for the faces, and draw the flancs 5, 2; 6, 7, parallel to the perpendicular 3, 4, obſerving to make them join the eſcarp of the foſsè; repeat this on every ſide of the polygon; thus the interior circumference of the place will be fortified; the flanked angle is in this ſyſtem placed in the middle of the ſide, betwixt the two angles of the polygon.

For the great foſsè, prolong the face of the counter-guard 20 fathoms from A to X, and draw the line XL to the oppoſite angle of the ſhoulder.

At the re-entering of the counterſcarp make a great re-
Fig. 32. doubt, and deſcribe it in the following manner. Prolong the perpendicular that was raiſed in the middle of the interior ſide indefinitely, beyond the re-entering angle of the counterſcarp; hereby you will divide this angle equally in

two

two as at B; then take B E equal to 16 fathoms; carry from E to F inwardly ſix fathoms, at the point F make the tranſverſal line L F I at rectangles with the perpendicular, and let F L and F I each of them be equal to E F; after this join E L, E I, for the two faces; continue to make F H equal to F E, and draw another tranſverſal line through H, whoſe parts H M, H N, muſt be equal to F L, F I, and join M B, N B, for the two interior faces; likewiſe draw the flancs M L, N I; laſtly, draw a foſsè ſix fathoms broad parallel to the exterior faces.

This being done, nothing remains but to add a falſe-bray quite round the counter-guards and the interior circumference of the place, excepting before the faces of the baſtions, and to deſcribe the two covert-ways and two glacis.

If it was deſired to begin the ſtructure of this ſyſtem by the flanked angle, make at the extremity A of the great ſemidiameter the angle C A H of 47 degrees and a half, becauſe the flanked angle of the octogon is found in the table to be 95 degrees, and take the line of defence A E of 140 fathoms upon the line A H, and from the point E draw the interior ſide D E C parallel to the exterior one; the reſt is performed as above.

Remarks upon the ſyſtem of Scheiteer *the* German.

We have inſerted this author's method, becauſe it has been aſſerted by *Sturmius*, a former profeſſor of mathematicks in the univerſity of *Francfort*, that M. *de Vauban* owes the invention of his ſyſtem of *New Briſac* to that we have laſtly laid down.

It is only neceſſary to caſt ones eyes upon theſe two ſyſtems to find at one view an intire difference betwixt them.

In

In this ſyſtem of *Scheiteer*, the thing that firſt ſtrikes us is the double glacis, with the double covert-way, which, as he makes it intirely deprived of any ſmall works to defend it, is certainly to be condemned, not only for the number of ſoldiers it requires for its defence, but alſo becauſe it lies quite open to be enfiladed. The next objection is the redoubt he makes at the re-entering angle of the counterſcarp, large enough to be expoſed to a bombardment, and yet too ſmall to afford any defence. Then the falſe-bray that runs round the counter-guards, which, beſides the common inconveniencies that attend this work, moreover gives the enemy a favourable opportunity of mounting the breach upon the moſt important piece of the whole ſtructure. Then again the interior baſtion, which ſeems to ſhew its two faces to invite the beſieger to batter them, and is only flanked by a feeble redan whoſe flanked angle is no more than 60 degrees. Laſtly, the falſe-brays that run round the body of the place become ſo much the more dangerous, becauſe they will be commanded by the beſiegers as ſoon as they become maſters of the counter-guards.

What compariſon can any one offer to make with all the works of this ſyſtem and thoſe of *New Briſac?* A re-entering curtin which allows to the beſieged two additional flancs, and before which is raiſed a good tenaille, can it in the leaſt reſemble a curtin which is wrought outwards ſo as to form a baſtion? Is it poſſible to miſtake a redan for a baſtioned tower, and a ſmall redoubt for a triple half-moon? What likeneſs is there betwixt a falſe-bray that ſerves as ſteps for the enemy to mount on the work it ſurrounds, and a very deep foſsè which M. *de Vauban* makes before his counter-guard, to render the acceſs to it more difficult? It is true, that in both the ſyſtems there is a great

great counter-guard with interior works; but is this ſufficient to ſay, that one of theſe fortifications is the copy of the other? Why did not *Sturmius* rather make his compariſon with the Count of *Pagan*'s ſyſtem, where the Counter-guard has, as in this, low flanes, and whoſe curtin briſed ſo much reſembles the two faces of the interior baſtion.

We muſt hence conclude, that nothing but vanity and envy moved *Sturmius* to make this unjuſt and critical compariſon, ſince he could with much reaſon and truth have drawn a parallel betwixt the ſyſtem of the Count juſt now mentioned, and that of *Scheiteer*.

This ſame critick is author of two ſyſtems, both of them pillaged from the two greateſt authors *Europe* ever produced; the one is intitled, *A ſyſtem of fortification*, preferable, according to a modern author, to that of *New Briſac*; the other he has ſet his name to, and is called, *The ſyſtem of Sturmius*. We ſhall not lay down either of them, in charity to the author, but proceed directly to thoſe of one of the admirable originals, which he has ſo miſerably endeavoured to copy.

The three ſyſtems of M. Coehorn.

Firſt ſyſtem.

THE late M. *Minno*, Baron of *Coehorn*, was all at once general of artillery, lieutenant-general of foot, Director-General of fortifications for the *United Provinces*, governor of *Flanders*, and of the fortreſſes upon the *Scheld*; and it muſt be ſaid to his honour, that his great knowledge, together with his long experience, raiſed his fame much more than any of his great employments.

This

This skilful man having perceived, that whatever expences were laid out to fortify the ramparts of a town, the ſuperior cannon of the beſiegers had ſoon deſtroyed them, and that often, after much time and coſt ſpent about the works, an enemy could make himſelf maſter of them in a fortnight or three weeks, imagined three different ſyſtems, wherein he covers the walls from the enemy's batteries, and at every ſtep lays ſo many traps in the way, that he pretends not indeed to render a place impregnable, but to ſell the conqueſt of it at a very dear rate to thoſe who would dare to attack it.

The mere inſpection of his plans ſtrikes us at once, and makes our curioſity deſirous to ſee his book; but ſcarcely is one engaged in the reading of it, but ſo many obſcure terms occur, ſuch few explanations concerning the ſtructure of the works, ſuch affectation to conceal the manner in which the works are lined, and the traps which could be ſtill added to the works; ſuch a tireſome detail of the defence that could be oppoſed, according to the different manners of attacks; and laſtly, ſuch long and tedious compariſons of his ſyſtems with thoſe of M. *de Vauban*, of whom he ſpeaks in a very ſlighting manner, that it is beyond any body's patience or courage to peruſe the book from one end to the other.

The Abbot *Deidier*, whoſe extracts concerning theſe ſyſtems we at preſent tranſlate, confeſſes, that was it not that he had undertaken to lay down the ſyſtems of different authors, that the publick might judge from their defects whether it is mere prejudice that has induced him to give the preference to M. *de Vauban*'s ſyſtem, he never could have gone through it. He adds, that upon this account he has more than once intirely read over M. *Coehorn*'s treatiſe with due deliberation, leſt his ſilence might make

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any one believe that the ſyſtems therein laid down were not to be reckoned in the leaſt faulty; and having compared and collected together the different parts of his book which could any ways be cleared up, he gives us the following ſtructures and profiles for the true and original ones of that celebrated engineer.

In M. *de Coehorn*'s firſt ſyſtem, an hexagon is given to be fortified, whoſe interior ſide is 150 fathoms, and whoſe horizontal line is ſuppoſed not more than four feet above the ſurface of the water, which is not in the leaſt uncommon in ſeveral places of the *United Provinces*. This ſuppoſition is much to be regarded, becauſe by this all the different profiles are regulated.

Let there be then given an hexagon to be fortified, divide the interior ſide A B equally in two at the point C; take 36 fathoms from C to D, and as many from C to E, that the whole curtin D E may contain 72 fathoms. At each extremity thereof make the diminiſhed angles D E H, E D M, 25 degrees each; the lines D M, E H, will be the lines of defence. Perform this operation on the other ſides of the polygon, and draw the lines of the gorges, as E L, at whoſe extremities ſet off 14 fathoms from E to R, and from L to S; then draw the line O P parallel to the line of defence, and at the diſtance of 23 fathoms within it. Let the ſaid O P meaſure 41 fathoms for the higher face of the baſtion, and draw the higher flanc O R, which you may make concave in the common manner; repeating this on every ſide of the figure, you will have deſcribed the interior fortifications of the place. Fig. 32.

Divide the ſpace that remains between the higher faces and the lines of defence into two parts, to one of which give 16 fathoms for the dry foſsè, and to the other ſeven fathoms for the thickneſs of the lower face, whoſe ram-

part has a parapet and banquet, and a ſmall terre-plein, which is but five feet broad; the length of the lower face is 76 fathoms.

For the orillon, prolong the lower face, and make A B eight fathoms, or eight fathoms and a half; let fall the
Fig. 33. perpendicular A C inwardly of 19 fathoms; upon the point C, and without the dry foſsè draw the perpendicular C E, likewiſe upon the point C, and make it four fathoms long. Take upon C A five fathoms and a half from C to F, raiſe upon the point F the perpendicular F H of 14 fathoms, and having joined H E by a right line, make the curve H B after the uſual manner, *viz.* by an equilateral triangle; continue the line E C four fathoms towards the dry foſsè, and thereon make three embraſures, whoſe uſe, as the author pretends, is to fire upon the enemy after he has made himſelf maſter of the exterior or lower face, and would be for advancing towards the tower by the means of the ſubterraneous gallery which runs along the ſaid face. Upon the point I raiſe another perpendicular I V of four fathoms, which will determine at the angle of the ſhoulder of the interior baſtion; at each extremity of this line you muſt make two gates, with draw-bridges, to keep a communication when required with the dry foſsè, and the ſpace that remains betwixt the two gates is to be taken up by two embraſures to enfilade the dry foſsè betwixt the flanc of the interior baſtion and that of the orillon; before theſe two gates, and before the ſide F of the tower, you muſt make a foſsè ſix fathoms broad, and full of water. The tower has a ſubterraneous battery of ſix pieces of cannon, and above is a platform, the ſuperior part of whoſe parapet is 24 feet broad for the ſides B A, B H, and but 16 feet broad for the other ſides. The vaults of the ſouterrains are covered over with earth ſix fathoms thick againſt the ſhock of bombs.

By

By what we have hitherto laid down it will not be difficult to conceive, by looking on the figure, how the middle flanc that determines at the extremity of the curtin is to be deſcribed. Its terre-plein, excluſive of the banquet and parapet, meaſures but ten feet broad; but in time of war the author would have it widened to 24 feet by means of a proper floor or ſcaffolding ſtrong enough to ſupport the cannon, which are placed thereon. The heights and lining of all the pieces will be diſplayed in a table we ſhall ſubjoin when we come to ſpeak of the profiles. Betwixt the middle flanc and the higher one there is made the dry foſsè before-mentioned; this, and all other dry foſsès in this firſt ſyſtem, muſt not be more than half a foot above the ſurface of the water, to prevent the enemy being able to make any intrenchments therein; without the middle flanc is a foſsè full of water, ſix fathoms broad. Fig. 32.

For the ſtructure of the tenaille, divide equally in two the part M N of the line of defence, comprehended betwixt the angle of the ſhoulder at M, and the angle of the tenaille at N; divide likewiſe equally in two the other part N D of the ſaid line of defence; repeat theſe diviſions upon the other line of defence, and draw right lines from one point of diviſion to another, and that will give you the faces, flancs, and curtin briſée of the tenaille, whoſe terre-plein is but four feet broad; betwixt the tenaille and curtin there is made a dry foſsè.

The great foſsè is 24 feet broad before the faces to which it is parallel; its depth is 13 feet at the eſcarp, 14 feet in the middle, and 12 feet at the counterſcarp.

Each demigorge of the interior ravelin are about 28 to 29 fathoms, and each face 45 fathoms. The terre-plein, excluſive of the parapet, is 15 feet broad, but toward the flanked angle it is 24 feet broad by 20 feet in length.

Quite round this ravelin runs a dry foſsè 16 fathoms broad, and it is bounded by a ſecond rampart called by the author, the *lower face*, and whoſe terre-plein, with the banquet, is but eight feet broad.

The ground whereon is raiſed the ravelin is ſix or ſeven feet higher than the dry foſsè. The angle of the gorge is cut off in a circular form, and in its middle is made a triangular caponiere of maſonry, and covered over with good timber, over which are flung three feet thick of earth; the wall runs eight feet higher than the timber, and hereby ſerves as a parapet for the terraſs, which the author calls a *bonnet*. Before this caponiere is made a dry foſsè ſet round with paliſades that join with the ramparts, and the paliſades that are placed before the faces of the caponiere are continued to the great foſsè to facilitate the retreat of the beſieged. The faces of all the works which have a dry foſsè before them muſt alſo be ſecured by paliſades.

In the dry foſsè that is betwixt the higher face and the lower one of the ravelin, at ſix fathoms diſtance from their extremities, is made a coffer four feet higher than the horizontal line; it is covered with planks, having over them one foot and a half of earth. At proper diſtances are made loop-holes for the muſquetry; this muſt be likewiſe practiſed for the caponiere, and other works of this nature. Behind the coffer inwardly are raiſed two banquets, from thence to fire over the coffer into the dry foſsè of the ravelin, and before is dug a little foſsè full of water ſix fathoms broad. The communication of the half-moon is preſerved by a ſtone or brick entry through the rampart towards the great foſsè; moreover, there is an additional caponiere at the flanked angle of the lower faces which has a communication with the half-moon by a gallery, as may be ſeen in the figure; and, to prevent the enemy's making

making uſe of this gallery to enter the ravelin, it can be filled with water whenever there is any occaſion.

The foſsè that runs before the lower faces is 18 fathoms broad, and is 11 feet deep at the eſcarp and 10 feet deep at the counterſcarp.

The counter-guard or cover-face is made up of a parapet and two banquets; its foſsè is 14 fathoms broad, 10 feet deep at the eſcarp, and but nine feet deep at the counterſcarp.

The covert-way is 12 fathoms broad, and is at the foot of the banquet three feet above the horizon, and goes off in a talus to the level of the water. The demigorges of the places of arms are each 22 fathoms, and their faces 28 fathoms. In them are made lodgments of maſonry, whoſe faces are 14 fathoms, and the demigorges 12; on each ſide is placed a traverſe with a double row of paliſades. All the covert-way is ſtuck with paliſades, which riſe and fall as neceſſity requires, and hereby they can be ſecured againſt the cannon-ſhot. The figure of them is ſufficient, without further explanation. Fig. 34.

Upon the glacis, at ſix fathoms from the faces of the place of arms, is made a covered coffer to ſtop the enemy's approach; and there are added wings thereto, from thence to fire upon the enemy when he had forced the paſſage through the coffer; they alſo ſerve for the communications thereto.

Table

Table of profiles.

	Interior height of the parapet above the horizon	Height of the lining above the horizon	Superior breadth of the parapet	Superior talus of the parapet	Superior breadth of the terre-plein
	feet	feet	feet	feet	feet
High curtin	18	6	20	2	24
Lower curtin and face of the tenaille	8	0	20	1	4
Higher face of the ravelin	14	8	20	2	15
Lower face of the ravelin	12	0	20	2	4
Covert-way	3	0	fathoms 20	3	fathoms 12
Higher face of the baſtion	22	10	feet 20	2	Full baſtion
Lower face of the baſtion	12	0	20	2	feet 5
Counter-guard	12	0	20	2	There are only two banquets, each 3 *feet* broad
Higher flanc	22	10	24	2	The baſtion full
Middle flanc	11	0	24	1	7
Lower flanc	3	0	24	1	The terre-plein only 4 *feet*, but it is to be made broader when cannon is mounted
The tower	22	16	24 3 ſides have but 16 *feet*, vide ſuprà	2	Full

TALUS.

All the works which are not lined have their exterior talus equal to their heights, and thoſe that are lined have a talus equal to the two thirds of their heights, from the ſuperior part of the parapet down to the lining.

The interior talus are every where equal to the height, excepting for the parapet, where it is conſiderably leſs.

The author will have the extremities of the lower face that join the orillon lined very carefully, the better to preſerve the orillon: this lining continues for ſeven or eight fathoms in length, but is not raiſed quite ſo high as that of the tower. This

This table ought to be read at the ſame time that the profiles are examined, for the parts are laid out in the ſame order as they are in the profiles; thus they will become more familiar and intelligible.

It muſt be obſerved, that there is a banquet three feet broad betwixt the parapet and terre-plein, but it muſt not be taken upon the meaſures allowed either for the parapet or terre-plein.

The author pretends to have a particular manner for the ſtructures of his brick-work, ſo that although he makes his walls double, with two counter-galleries, yet *they do not require but the three-eighths of the bricks which are employed in any other modern ſtructure.* With regard to this article, we will here lay down the diſcovery of this ſecret, for ſo the author deſigned it to be. A *french* officer of note was ſo happy as to find it out as he paſſed through *Manheim*, whoſe fortifications are built according to the ſcheme and inſtructions of M. *de Coehorn.* This ſtructure is very plain and eaſy, yet at the ſame time ſo ingenious, and does really ſo conſiderably diminiſh the expence, that it is worthy of being communicated to the publick.

The ſuperior part of the walls is generally allowed five feet, with a fifth part for the talus above the foundations, which are made two, three, or four feet thicker, and often more, according to the quality of the earth. To this are added counter-forts at the diſtance of every 18 or 15 feet. This ſtructure, which makes the expences run very high, eſpecially in great places, and in ſuch where the foſsè muſt be made very deep, appeared nevertheleſs hitherto ſo abſolutely neceſſary to withſtand the ſwelling of the earth of the rampart, that no engineer has ever attempted to make any conſiderable variation therein for the works he has directed. M. *de Coehorn* indeed did go beyond theſe rules,

but

but made ſuch a myſtery of his invention, that doubtleſs his ſecret would have died with him, if he had not employed it at *Manheim*; hereby was it luckily diſcovered. Let us then ſee how far it may be of uſe.

He makes the ſuperior part of his walls but three feet thick, with a talus of one ſixth part of the height, and even leſs, which he continues to the bottom of the foundation, and never places any counter-forts; but as the ſwelling of the earth would ſoon overthrow ſuch weak walls, by diſordering the ſeveral rows of ſtones or bricks, were they laid horizontally, as A, which has ever been cuſtomary, he places them perpendicular to the line of talus, as at B, ſo that when the earth that begins to ſwell from the top of the rampart, and ſo on to the bottom at an angle of 45 degrees, preſſes the uppermoſt row, it only preſſes it ſo much the cloſer to the ſecond, inſtead of diſordering it; the effect is the ſame from the preſſure of the ſecond upon the third, and ſo on to the laſt row of all. Theſe walls can never be overthrown but by having their foundations ſapped, and nothing can be more ingeniouſly or better contrived to diminiſh the expences of theſe parts of fortification; but it is a queſtion whether the beſiegers cannon could not very ſpeedily demoliſh them; perhaps being ſenſible of this, M. *de Coehorn* is ſo particularly careful in hiding them from the enemy's batteries; if ſo, the prime expences of the works of earth raiſed for that purpoſe, with the charges required to keep them up, joined to thoſe of the walls, muſt certainly by far exceed the ſums which are neceſſary for the common ſtructure. However, it is certainly an admirable invention for ſuch walls which are only deſigned to reſiſt the ſwelling of the earth, and in ſuch caſes it ought to be preferred, eſpecially ſince there have been inſtances of its having ſtood much firmer,

Fig. 35.

though

though the lays of the other ſtructure were faſtened together with cramp-irons.

Remarks upon the firſt ſyſtem of M. de Coehorn.

There is not a work in this ſyſtem but what is conformable to the maxims of a good fortification; each part is well defended; the flanked angles are of a reaſonable greatneſs, being 70 degrees; the heights are the better proportioned, becauſe, without hiding the defences, the walls are nevertheleſs covered from the enemy's cannon; and if the lower curtin ſeems faulty by not being drawn in a right line, ſo that the miner might be reckoned in ſafety as ſoon as he had placed himſelf in the re-entering angle, yet by caſting ones eyes upon the profile, this ſeeming error will ſoon diſappear; for becauſe the ſuperior part of the parapet riſes but three feet above the horizon, and of conſequence its embraſures are but one foot above the water of the foſsè, the miner would be more expoſed therein than in any other part; moreover, attempts of this nature would ſcarcely be made againſt works that were ſo low, ſince they would be too hazardous; again the number of traps to which this ſyſtem expoſes the beſiegers, who can never find any ground where they can lodge themſelves, the ramparts being of a very moderate thickneſs, and the dry foſsès, wherein they would meet with water before they had dug half a foot deep, and wherein alſo they are continually expoſed to ſome hidden fire that cannot be overcome but with much trouble; not to reckon ſeveral other methods that the beſieged can employ to diſturb them (a detail of which the author has given us in his book, though he ſays that he has reſerved a great deal from the publick.) We may hence conclude,

that this ſyſtem of fortification would be the moſt excellent, was it not that it requires an exceſſive numerous garriſon becauſe the chief of its defence depends upon muſquetry, and that it is very liable to ſurprizes. What havock would not an enemy make, if by the means of a falſe attack made againſt one front, he could ſurprize one or two redoubts of the ſaillant angles, or even the half-moon? The batteries he ſhould raiſe againſt the tower would quickly deſtroy this moſt eſſential part of the ſyſtem, and in a very few days the place would be juſt on the brink of ruin; for, as we have juſt now obſerved, what a prodigious number of troops are abſolutely neceſſary to man all theſe different works to prevent their being ſtormed, ſince the leaſt of them cannot be left any ways unmann'd (not even one of the coffers of the glacis) without being in very immediate danger; and then, as we have already ſaid, the expences are not ſo very moderate as the author would inſinuate. It muſt be allowed, that his manner of lining his works becomes leſs expenſive than that commonly practiſed; the calculations he has given us in his book were not at all neceſſary to prove it, but the conſtant attendance that muſt be given to repair the works that are not lined proves at laſt as extravagant as the ſtructure of the ſtrongeſt walls, ſince we know by experience that any fortification whatſoever that is intended to ſubſiſt any time, anſwers much better our expectations in every reſpect when it is lined, than otherwiſe. To conclude, we ought never to judge of the excellency of any ſyſtem by the number of out-works and traps it contains; if we did, that one would claim the greateſt ſhare of our applauſe and admiration that was conformable thereto, provided care was taken to have each part properly flanked; but things ought to be ſo managed, that by putting a place in a ſtate of

of defence, you ought not to be obliged to leave others deſtitute and helpleſs, or diminiſh greatly the ſtrength of the army; the conſequences of either of theſe articles muſt infallibly become very advantageous to an enemy, and as fatal to thoſe who were guilty of ſuch folly. However, moſt of the modern ſyſtems have failed in this point, and the old ones have been diſapproved by not being agreeable to ſome very eſſential rules of this art; but nothing ought to be admitted as worthy of an intire approbation but what can make the maxims of fortification agree with ſuch neceſſary precautions that muſt be taken, not to weaken the ſtrength of a whole kingdom under pretence of fortifying two or three cities.

The ſecond ſyſtem of M. de Coehorn.

FOR an example of the ſecond ſyſtem of M. *de Coehorn*, an heptagon is given to be fortified whoſe interior ſide is 126 fathoms, and wherein the horizontal line is only three feet higher than the water.

To deſcribe it prolong the ſemi-diameters, and take 72 fathoms for the capital of each baſtion; at the extremity of the capital make on both ſides an angle of 40 degrees, and this will render the angle of the baſtion 80 degrees. Then take upon the interior ſide 30 fathoms for each demigorge, and fixing one leg of your compaſſes at the angle of the baſtion, open the other to interſect the extremity of the demigorge, and upon this indefinite arch ſet off 30 fathoms for the middle flanc. This arch only ſerves to determine the flanc, whoſe concavity is deſcribed by an equilateral triangle, having the length of the flanc for baſis. This muſt be carefully obſerved wherever you meet with this manner of ſtructure, either in this ſyſtem or in the following. Fig. 36.

The retreat of the orillon is drawn in a right line with the angle of the oppoſite baſtion; its ſally outwards is 10 fathoms, at the extremity of which begins the convexity after the ordinary manner, obſerving to leave a right line of 66 fathoms for the length of the face.

The retreat of the curtin is taken upon the gorge of the baſtion; the high flanc is 40 fathoms long; the baſtion is full.

The tenaille is deſcribed by prolonging the faces 10 fathoms; then fixing, as before, one leg of your compaſſes at the angle of the oppoſite baſtion, deſcribe an arch to paſs at the extremity of the face prolonged, and take 20 fathoms for the length of the lower flanc; this determines the lower curtin that contains 36 fathoms.

Behind the tenaille, towards the place, there is a dry foſsè, and before it is made one full of water 10 feet deep and ten fathoms broad.

Beyond this is a dry foſsè 20 fathoms broad at the faces, and drawn parallel to them.

Next to this foſsè deſcribe a rampart, likewiſe parallel to the faces, whoſe ſuperior breadth, including the banquet and parapet, is 29 feet, underneath which are made vaulted galleries; at the re-entering angle of this rampart make an interſection on each ſide of 15 fathoms, to open a paſſage to the half-moon, which is covered by two flancs deſcribed from the oppoſite ſaillant angles, and is allowed 18 fathoms in length. The dimenſions of their rampart are the ſame as thoſe of the counter-guards; they are alſo vaulted.

For the half-moon, raiſe upon the middle of the curtin a perpendicular of 125 fathoms, at whoſe extremity on each ſide make an angle of 35 degrees; hereby the flanked angle will be 70 degrees. The faces are 50 fathoms

thoms long, and have vaulted galleries beneath their ramparts.

The dry foſsè that there is betwixt the faces of the half-moon and the little redoubt is 12 or 14 fathoms broad. This redoubt is of ſtone or brick-work. The diſtance that is left betwixt the interior and exterior wall is 16 feet. They are covered with ſtrong Timber, upon which is raiſed a parapet of earth, with a banquet and terre-plein. The length of each face is 14 fathoms.

The great foſsè runs parallel to the out-works hitherto deſcribed, and is 24 fathoms broad and 12 feet deep.

The next work, which the author calls the *firſt counter-ſcarp*, is deſcribed by making it at firſt 20 fathoms broad on every ſide. Then are made the redoubts at the re-entering angles, whoſe faces are each 14 fathoms. Their height above the covert-way is nine feet twelve fathoms diſtant from each face. There are drawn two parallel lines, whoſe interſection forms a ſaillant angle, wherein fixing one leg of your compaſſes, deſcribe on each ſide an arch with an interval of 15 or 16 fathoms, and this gives you the parts of the curtin briſée. Afterwards take upon the exterior border of the counterſcarp 25 fathoms for the flanc, that muſt be drawn at the extremity of the curtin briſée, whoſe concavity is deſcribed in the uſual manner; and thus will you determine the faces of the counterſcarp.

The rampart of this work conſiſts in a parapet, a banquet, and a ſmall terre-plein, a detail of whoſe meaſures is given in the next table of profiles. What remains is the covert-way, that is two feet lower than the horizon, and goes with an eaſy talus to the very ſurface of the water.

The

The redoubts that are placed in the counterſcarp, juſt before the flanked angle of the half-moon, have ten fathoms for each face, and ſeven fathoms for each flanc; but thoſe that are before the flanked angle of the baſtion are allowed twelve fathoms for a face, and only four fathoms for a flanc. They are raiſed ſeven feet higher than the covert-way, in which are made traverſes which anſwer upon the extremity of each face of the firſt counterſcarp, underneath whoſe curtin-briſée is made a coffer with a gallery of communication to the redoubt. The whole work is bordered with paliſades, diſpoſed in the ſame manner as is repreſented by the dotted lines in the figure.

The ſtructure of the ſecond counterſcarp varies in nothing from that of the foregoing ſyſtem. Its glacis extends 16 or 20 fathoms.

Table

Table of profiles.

	Interior height of the parapet above the horizon	Height of the lining above the horizon	Superior breadth of the parapet	Superior talus of the parapet	Superior breadth of the terre-plein
	feet	feet	feet	feet	feet
High curtin	22	8	20	2	24
Lower curtin and face of the tenaille	11	5	24	1	3
Redoubt of the half-moon	14	8	14	1	6
Face of the half-moon or ravelin	$12\frac{1}{2}$	0	20	1	6
First counterſcarp	10	0	20	1	5 At the extremity of this terre-plein the covert-way that remains is two *feet* and a half below the horizon, and goes off in a talus to the ſurface of the water
Second counterſcarp	$4\frac{1}{2}$	0	16 fathoms This is the glacis	4 feet and a half ſlope of the glacis	12 fathoms This is the covert-way
Face of the baſtion	28	$13\frac{1}{2}$	feet 20	2	Full baſtion
The lower face	14	0	20	1	feet 6
The high flanc	28	0	24	2	Full baſtion
The mean flanc	18	8	24	2	8 fathoms including the interior talus
Lower flanc	10	4	24	1	feet 4

TALUS.

Thoſe works that are not lined have their exterior talus equal to their heights; thoſe that are lined have a talus two thirds or three fourths of their heights, as far as they are lined.

All the interior talus are equal to their heights.

What

What has been ſaid concerning the banquets in the foregoing ſyſtem, muſt be obſerved in this and in the following. All the ſaillant angles are raiſed two feet higher than what is ſet down in the table; this the author prudently deſigned to prevent an enfilade.

We have given a draught of the paliſades that were made at firſt, by M. *de Coehorn*'s direction; they are fixed in a long piece of timber, whoſe ends are ſo let into two poſts which ſupport it, that the points of the paliſades are turned either upwards or downwards at pleaſure. Thus the cannon cannot damage them, for they are kept down as long as it continues firing, and they are turned upwards as ſoon as the enemy is drawing near the covert-way, to drive the beſieged thence. Theſe paliſades are to be recommended for their being cheaper than the others, alſo becauſe in time of peace they may be brought under cover to preſerve them; though ſhould they remain in the works, they would laſt conſiderably longer than thoſe who having one end ſtuck into the ground are liable to be rotten in a ſhort time.

Remarks upon the ſecond ſyſtem of M. de Coehorn.

What has been remarked upon the firſt ſyſtem, will help us to form a judgment of this, whoſe faults are much more ſenſible, and we may ſee, by the ſtructure and profiles of the third, that had the author continued to invent other ſyſtems, he would have produced one that would have required half the inhabitants of a kingdom for the defence of one city only. What may be ſaid on this point for his juſtification is, that theſe faults ſo conſiderable in a city not belonging to a republic, become of little conſequence in a city belonging to a republican ſtate, ſuch as thoſe of *Holland*,

Holland, which was the country that altogether employed M. *de Coehorn*. Theſe ſorts of ſtates very ſeldom are engaged in other wars than thoſe they undertake for the preſervation of their liberty, and whenever that is at ſtake every thing is effected to keep it up; each individual contributes, as much as he is able, towards its preſervation; not only to avoid falling under a foreign government, but to render himſelf worthy of being raiſed to ſome eminent poſt; and inſtead of there being required within a town a garriſon to defend it, and keep its inhabitants in awe, every inhabitant that's able ſerves for a ſoldier, and is ready to defend the out-works, and diſpute the ground with the enemy ſtep by ſtep at the hazard of their lives. In the like caſe it is proper to increaſe the number of outworks and traps to keep the enemy at a greater diſtance, and there haraſs him the longer, ſo that hereby having ſuffered very great loſſes, he will perhaps retire, and be diſcouraged from puſhing his attacks to the body of the place, where, from what had paſſed before, he may judge that the inhabitants then being on the point of loſing their liberty, will make a braver and more vigorous defence than any garriſon of ſoldiers whatſoever. All this ſuppoſes a republic rich and populous enough to ſtand by itſelf; for was there any occaſion for auxiliary troops, and the war laſted any time, theſe expences, joined to thoſe of the fortifications, would certainly impoveriſh the ſtate; beſides, the vigilance of theſe mercenaries would never equal that of the towns-people, which might endanger them to be ſurprized.

Therefore let us conclude, that if M. *de Coehorn*'s ſyſtems are advantageous in ſome circumſtances which he regarded when he did invent them, they are likewiſe very faulty and deficient in innumerable others, and that it is even

dangerous to put them in execution, with all the ſuppoſitions he makes, becauſe the revolutions of wars often alter the face of things, and it may happen that thoſe very advantages become quite prejudicial, contrary to all former expectations.

The third ſyſtem of M. de Coehorn.

THE author propoſes to fortify by this third ſyſtem an octogon, wherein the horizontal line is ſuppoſed to be five feet above the water.

The interior ſide is 110 fathoms. Each demigorge is allowed 21 fathoms. The capital is 64 fathoms; at whoſe extremity, on either ſide of the line, make an angle of 42 degrees and a half, hereby the flanked angle is 85 degrees. Make each face 54 fathoms, then from the angle of tenaille, upon the line of defence, ſet off 32 fathoms inwardly for half of the curtin-briſée, and the whole will be 64 fathoms; afterwards, fixing one point of your compaſſes upon the flanked angle of the baſtion, deſcribe two arches, one of which muſt paſs at the oppoſite extremity of the great curtin, and the other at the oppoſite extremity of the curtin-briſée. Upon the firſt of theſe arches take 36 fathoms for the higher flanc, and upon the other only 30 fathoms for the flanc of the tenaille or lower flanc; their concavity muſt be deſcribed as it has been laid down above. This done, deſcribe the orillon. There is a dry foſsè betwixt the flancs, and one alſo betwixt the two curtins; but to prevent theſe foſsès having a communication with one another, at both extremities of the curtin-briſée is dug a large baſon full of water.

The

The foſsè that is betwixt the face of the principal baſtion and the detached baſtion is 20 fathoms broad. At the re-entering angle of this foſsè take 38 fathoms for each demigorge, and upon the middle of the great curtin raiſe an indefinite perpendicular to extend 100 fathoms beyond this angle; theſe 100 fathoms are the length preſcribed for the capital of the detached baſtion. Draw from the extremity of this capital right lines to the extremities of the oppoſite demigorges of the oppoſite detached baſtions, and within theſe lines, 23 fathoms diſtant, draw others parallel to them, upon which take 31 fathoms for each interior face.

The higher flanc is deſcribed by fixing one leg of your compaſſes at the extremity of the capital of the oppoſite detached baſtion, and with the other deſcribe an arch, which paſſing at the extremity of the interior face, will interſect the demigorge; this deſcribes the higher flanc that is 34 fathoms long.

The dry foſsè that is made betwixt the higher face and the lower one, is 16 fathoms broad. The lower face is 62 or 64 fathoms in length. The orillon, the lower flanc, and what remains, is deſcribed as in the firſt method, excepting that the orillon is brought more outwards, the better to cover the lower flanc that falls directly upon the extremity of the demigorges.

Betwixt the two higher flancs is made a caponiere ſix feet above the horizon, covered over four or five feet thick of earth, to be proof againſt fire-works. Quite round it is dug a dry foſsè four fathoms broad, and three feet deeper than the horizontal line. The exterior border of this foſsè is ſurrounded by a gallery whoſe breadth is ſix feet, and its height ſeven feet; it is covered with planks and with earth, and ſerves for an aſcent to the terre-plein of

the baſtion that is raiſed 15 feet above the horizon. Galleries are alſo made round the lower faces. The flanked angles of the detached baſtions are 90 degrees.

The great foſsè is parallel to the lower faces, and is 24 fathoms broad. The demigorges of the half-moon are 28 fathoms each, and each of its faces 45. The dry foſsès betwixt the higher and lower faces are 16 fathoms; therein are made coffers, caponieres, galleries; and, as in the firſt ſyſtem, the flanked angle is 65 degrees.

Laſtly, there is raiſed before the detached baſtion a counter-guard, whoſe foſsè is 12 fathoms broad. The covert-way and glacis is finiſhed as in the other two plans.

We have ſubjoined to each ſyſtem of this illuſtrious author a table of profiles. This may ſatisfy the curioſity of the reader, without giving the figures; beſides, he may deſcribe by their help, with a ſcale ſufficiently large, an exact profile of the ſection of any part of the body of the place, or of the out-works.

Table

Table of profiles.

	Interior height of the parapet above the horizon	Height of the lining above the horizon	Superior breadth of the parapet	Superior talus of the parapet	Superior breadth of the terre-plein
Face of the baſtion of the place	feet 26	feet 5	feet 24	feet 2	Full baſtion
Higher face of the ravelin	16	7	20	2	feet 15
Lower face of the ravelin	9	0	20	2	5
Covert-way	$2\frac{1}{2}$	0	16 fathoms This is the glacis	2 feet and a half ſlope of the glacis	fathoms 12
High curtin	22	6	feet 24	2	feet 27
Lower curtin	11	0	24	1	7
High face of the detached baſtion	21	9	20	2	Full baſtion
Lower face of the detached baſtion	11	0	20	2	feet 5
Counter-guard	10	0	20	1	4
High flanc of the place	22	7	24	2	Full baſtion
Lower flanc of the place	12	0	24	2	feet 8
High flanc of the detached baſtion	19	7	24	2	Full baſtion
Lower flanc of the detached baſtion	9	0	24	2	feet 7

TALUS.

The interior and exterior talus are deſcribed as in the two foregoing ſyſtems.

The

The tower is lined 15 feet above the horizon; and its parapet, which is of earth, is as high as the higher face.

The lining of the lower faces of the detached baſtions is continued for the ſpace of ſix or ſeven fathoms, for the ſafety of the towers at the orillons.

The different depths of the ſeveral foſsès muſt be mentioned.

The foſsè betwixt the baſtion of the place and the detached baſtion is 13 feet deep at the eſcarp, 15 feet in the middle, and 14 feet at the counterſcarp.

The foſsè betwixt the detached baſtion and the counter-guard is 12 feet at the eſcarp, 14 feet in the middle, and 13 feet at the counterſcarp.

The foſsè betwixt the half-moon and the covert-way is eight feet deep at the eſcarp, and ſeven feet at the counterſcarp.

Laſtly, the foſsè betwixt the counter-guard and the covert-way is ſeven feet deep at the eſcarp, and five feet at the counterſcarp.

A cloſing remark.

We may conclude, after having carefully examined the ſyſtems of the different authors, that there is not any one of them which anſwer the end of fortification ſo well as that of *New Briſach*. The expences are not exceeding great; and for its defence, a moderate garriſon, under the conduct of a brave and intelligent governor, would coſt much time, with infinite loſs and trouble, to any enemy that ſhould undertake to beſiege it. However, as the conſtant application and practice of any art, are the means whereby it is carried to any degree of perfection, M. *de Vauban* would certainly have amended this ſyſtem, if his other

other great employments had allowed him time and leiſure. But it muſt not be imagined that he deſigned to have made a new circumference, or other different outworks, this would have required greater expence, and a more numerous garriſon, both which he was ever ſtudious to avoid. To judge by the ſtructure of *New Briſach*; it is to be ſuppoſed that this great man had two principal points in view; the one, to prevent the beſiegers deſtroying the circumference of the body of the place before they puſhed their attacks as far as the glacis; and the other to have flancs of a ſufficient extent to oppoſe the batteries which the beſiegers never fail raiſing againſt them upon the ſaillant angles of the counterſcarp. Now as to the firſt, it would have been much better if he had ſo covered the circumference of the body of the place, that only the ſummit of its parapet could have been ſeen from the field; indeed, by theſe means, the cannon fired through the embraſures could not have prevented the beſiegers advancing as far as the glacis, without much danger, but the number of barbet-batteries that are often removed from one place to another, without much difficulty, haraſs the enemies greatly, and oblige them to keep their diſtance. With reſpect to the ſecond article, the flancs of the counter-guards might have been deſcribed much greater, and the foſsè traced of the ſame breadth at the ſaillant angles, the counterſcarp to be directed to the angles of the ſhoulder; thus the foſsè would become broader at the re-entering angles than at the ſaillant angles; therefore the beſiegers batteries at theſe parts againſt the flancs would be greatly inferior to thoſe of the place, unleſs a vaſt quantity of the earth that makes up the parapet of the covert-way was cut away, which would

be

be a hazardous attempt where the defences of the place were not as yet damaged.

What has been remarked as to the enlarging the flancs of the counter-guards, may ſerve as an obſervation for the flancs of the tower-baſtions and of the curtins-briſée; for it is evident, that ſince even after the taking of the counter-guards, the circumference remains entire, and that the enemy cannot bring up any cannon but with immenſe trouble upon theſe counter-guards, their attempt would prove ſtill more ineffectual, if inſtead of one or two cannon to prevent their lodgment, they were oppoſed by ſeven or eight in each flanc. It would be better to leave the half-moons without flancs, and only to give them to the reduits.

Of the ſituation of places.

IN a treatiſe of fortifications, it is indiſpenſibly neceſſary to make ſome general obſervations concerning the different ſituations of places. As a town intended to be fortified is but very ſeldom ſituated in ſuch an advantageous manner as an engineer could deſire, was he to make choice of the ground, which for ſeveral reaſons in many circumſtances cannot be changed, whether it is in repairing any old fortifications, or fortifying towns already built, or in ſome works of temporary Fortifications, as thoſe neceſſary to guard the paſſage of a river or a defilee; therefore it is requiſite not to be ignorant of the advantages and diſadvantages of different ſituations.

1. Places built upon high mountains can ſcarcely ever be fortified with ſuch perfection as thoſe ſituated in a plain; but they have theſe advantages, that it is with the utmoſt

The exteriour Sied AB 156 Fathoms
Supposing the line of Defe. BD or AC
120 Fathoms

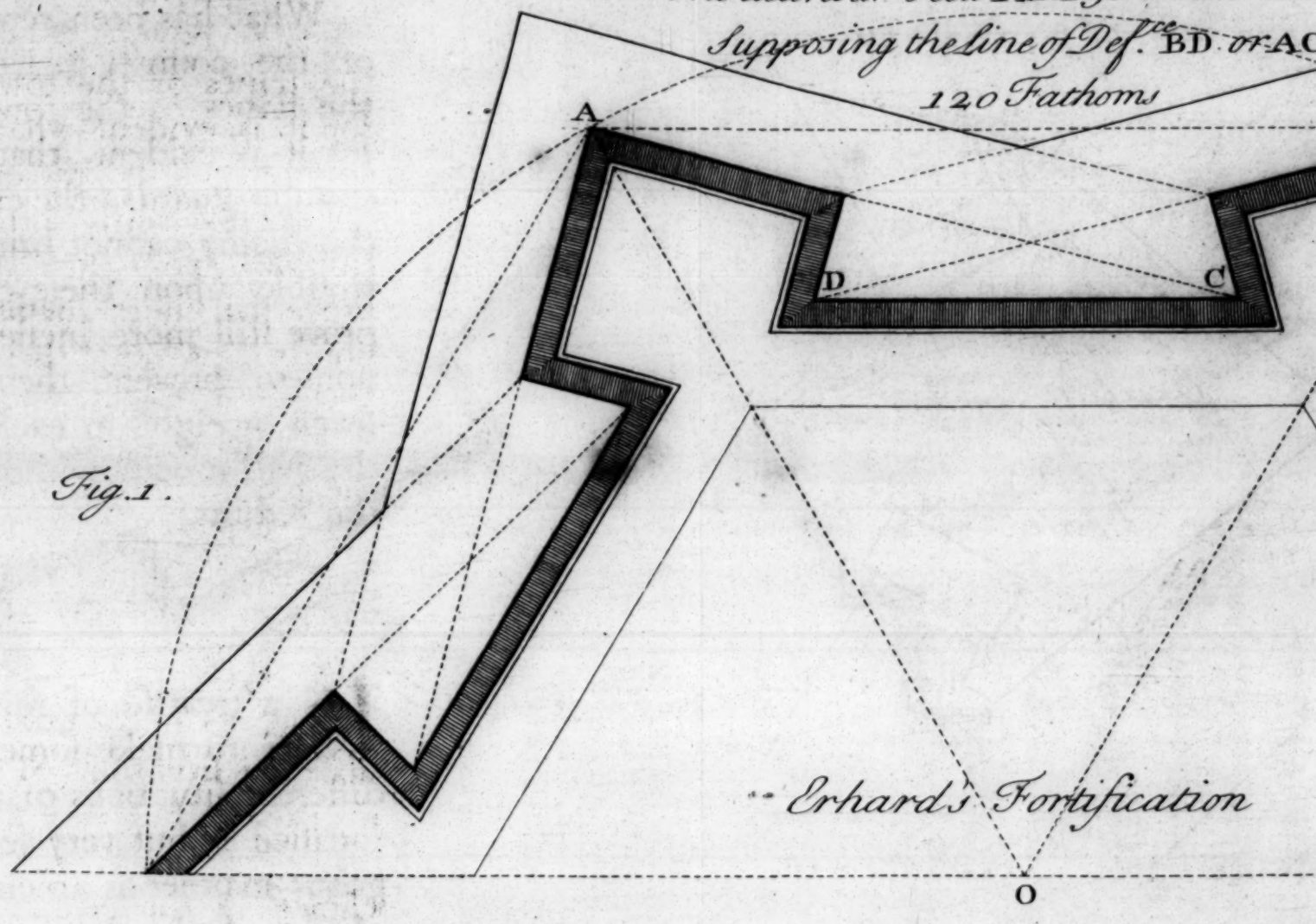
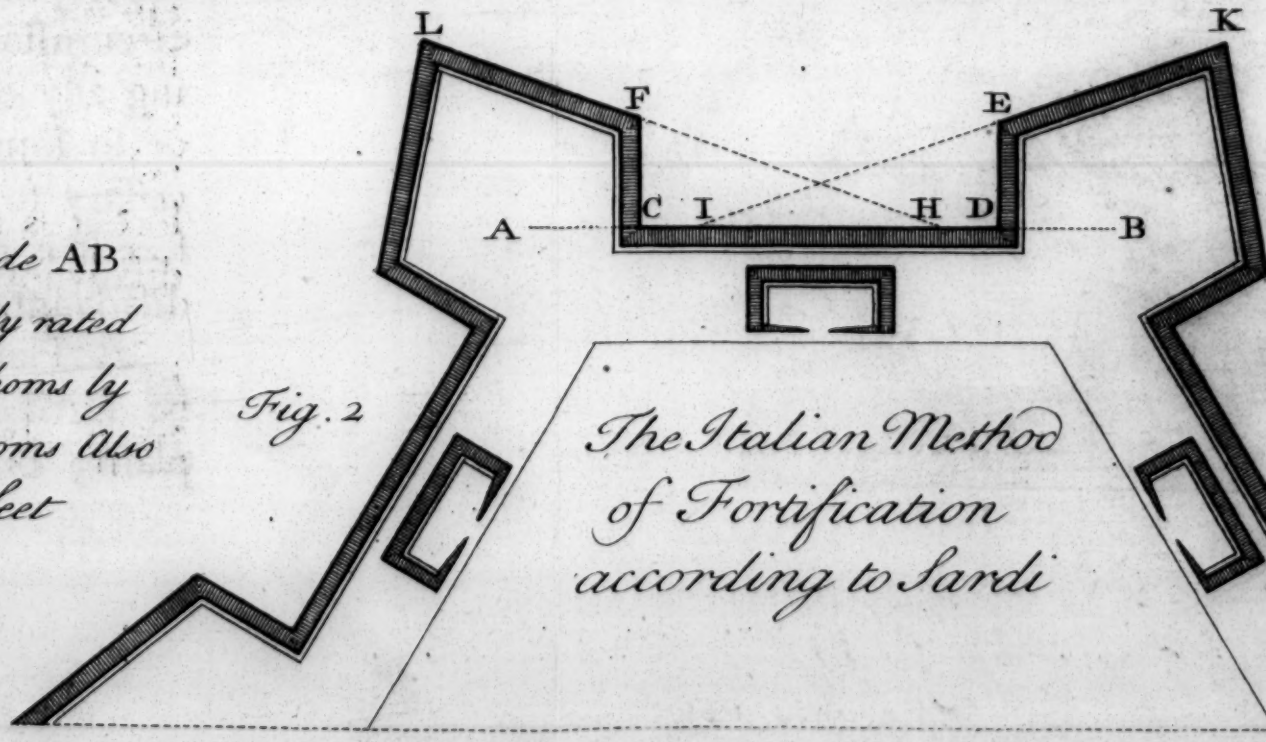


Fig. 1.

Erhard's Fortification



The interior Side AB has been variously rated by Some at 160 fathoms by Others at 130 fathoms Also at 133 fathoms 2 feet

Fig. 2

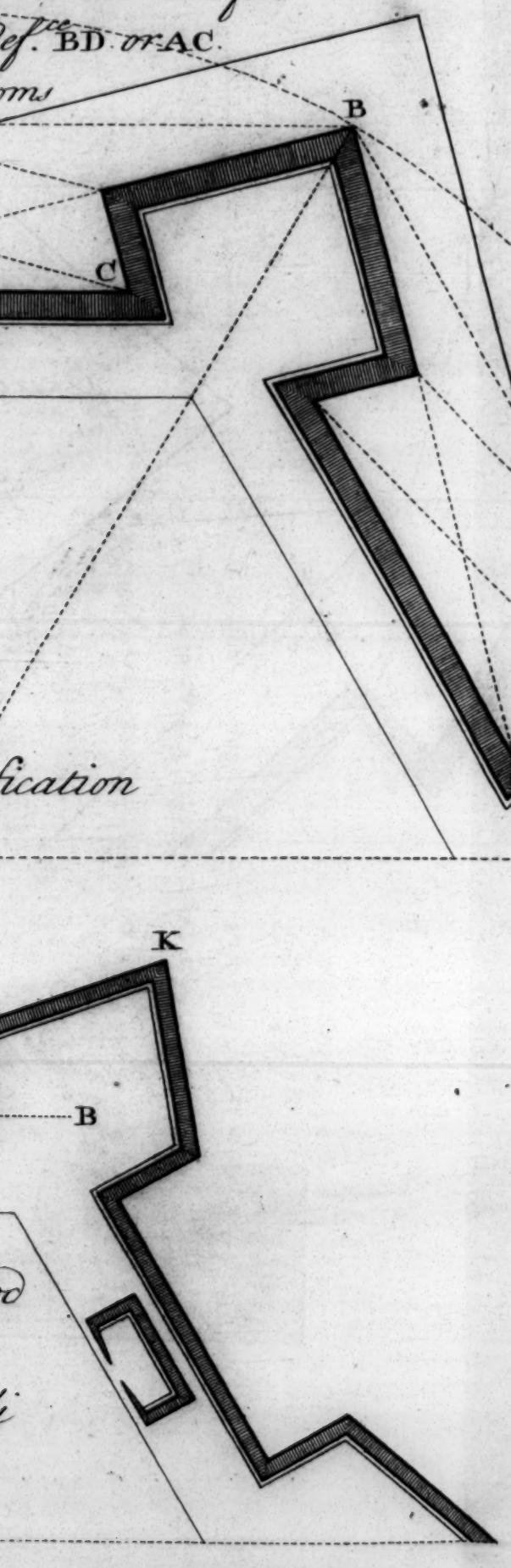
The Italian Method of Fortification according to Sardi

The fifteen Plates Numbers 27 to 41 are to be placed at page 168.

6 Fathoms 2 feet

ef. BD or AC.

oms



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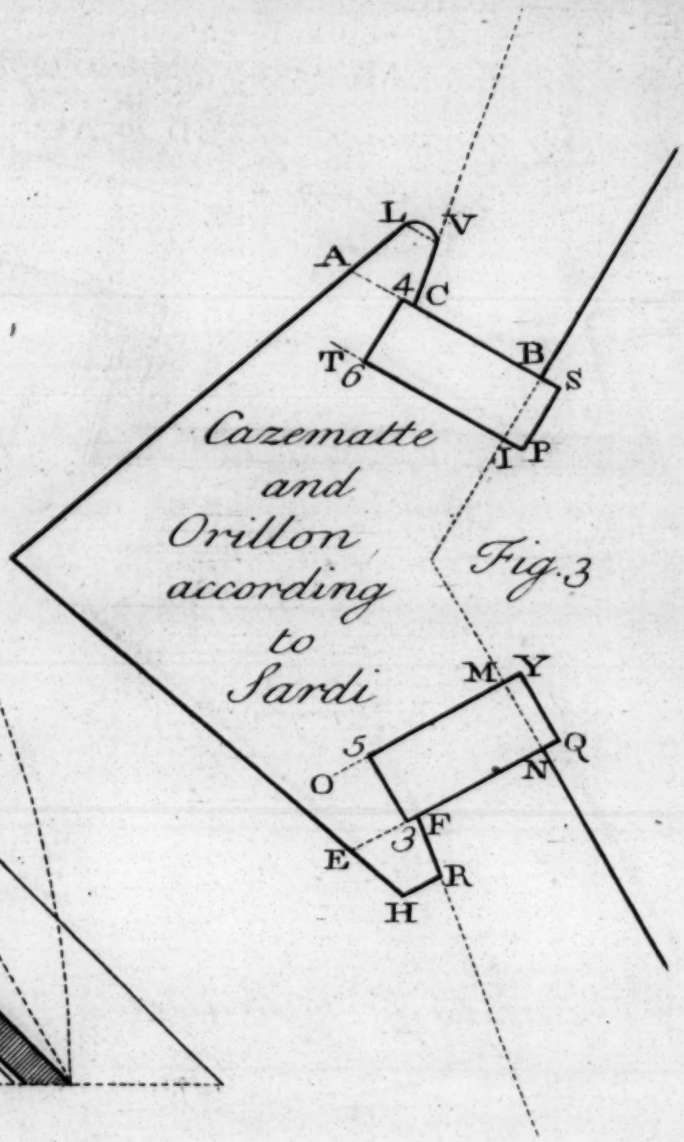


Fig. 3

The Profil of the high & Low Flank

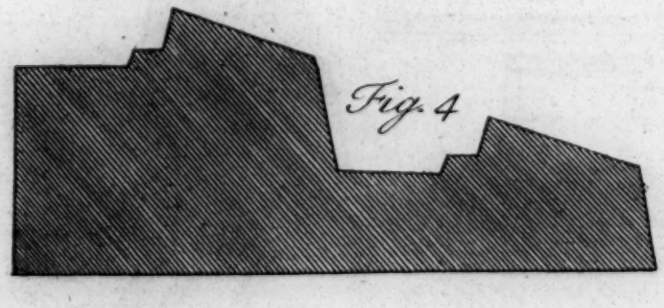


Fig. 4

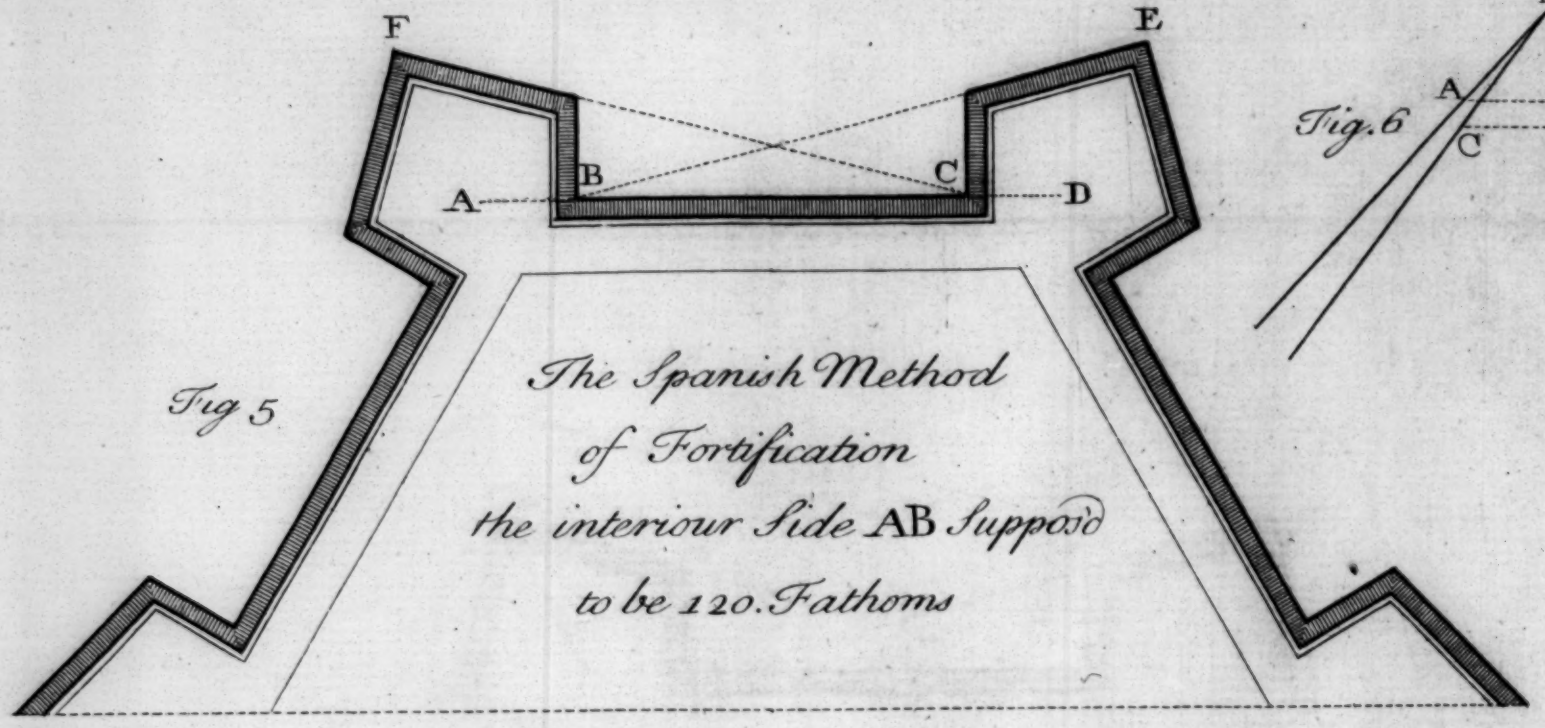


Fig 5

The Spanish Method of Fortification the interiour Side AB *Supposd to be 120. Fathoms*

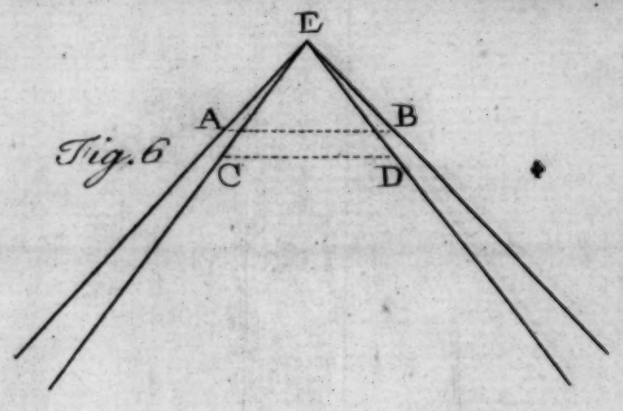
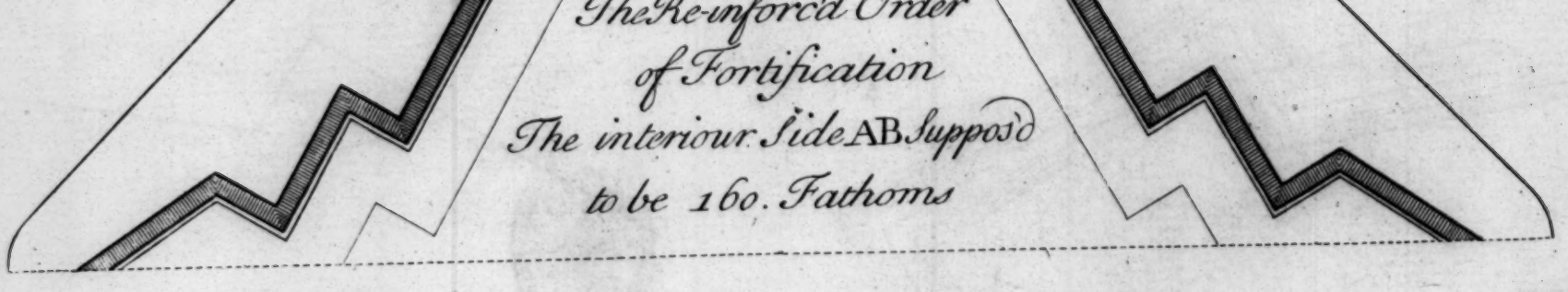


Fig. 6

Fig. 7

The Re-inforc'd Order of Fortification The interiour Side AB *Supposd to be 160. Fathoms*



The Re-inforcd Order
of Fortification
The interiour Side AB Suppos'd
to be 160. Fathoms

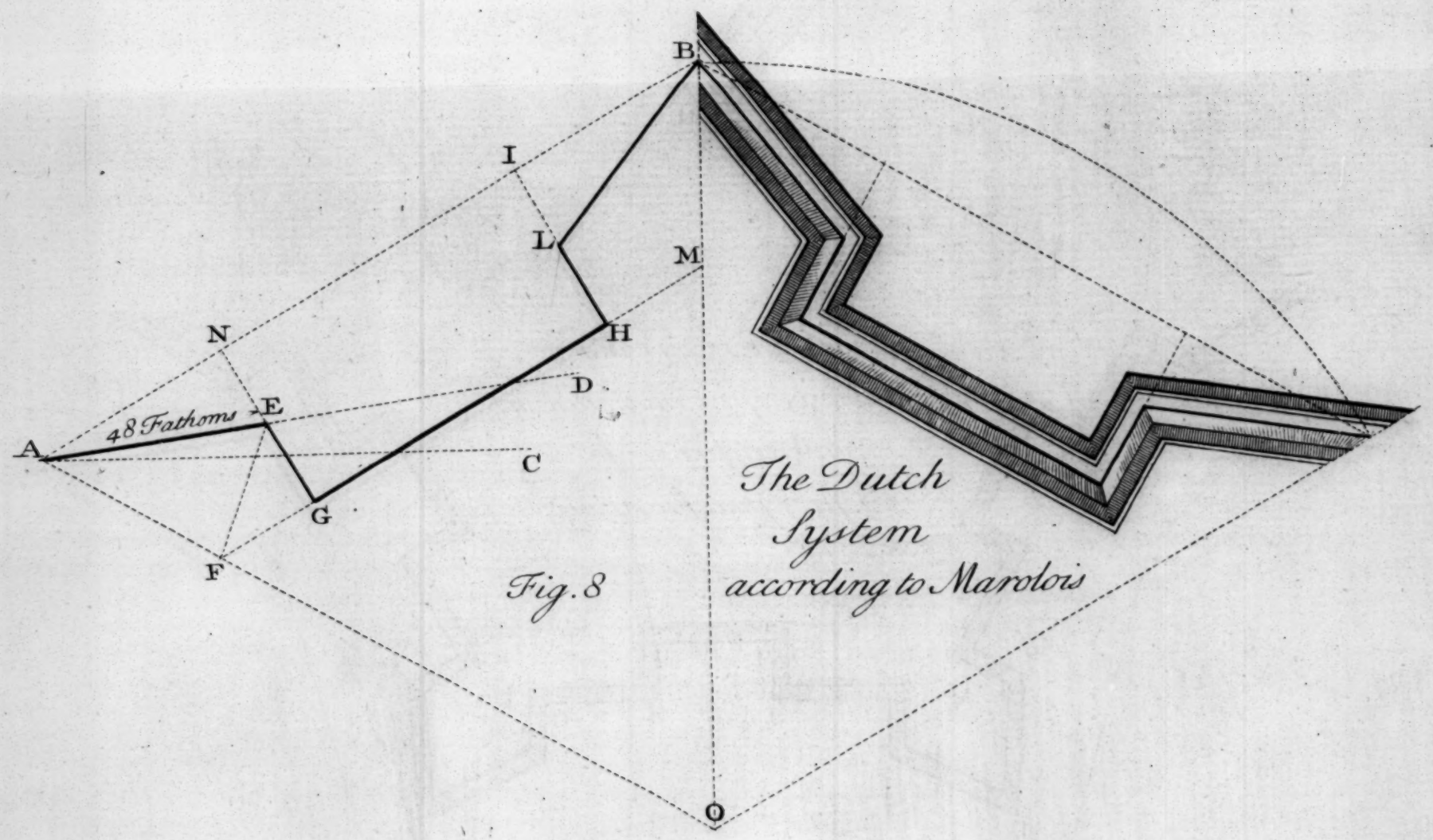
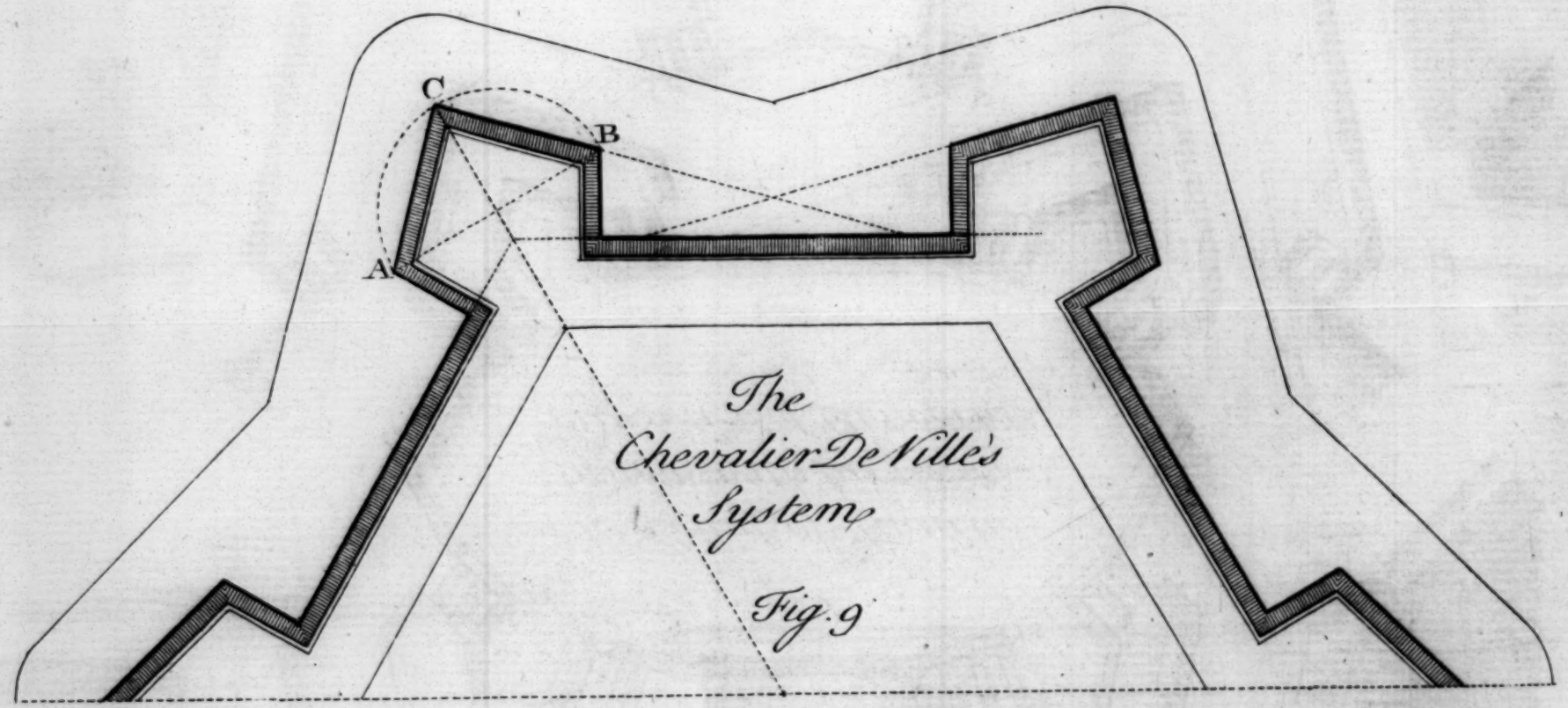


Fig. 8

The Dutch
System
according to Marolois



The
Chevalier De Ville's
System

Fig. 9

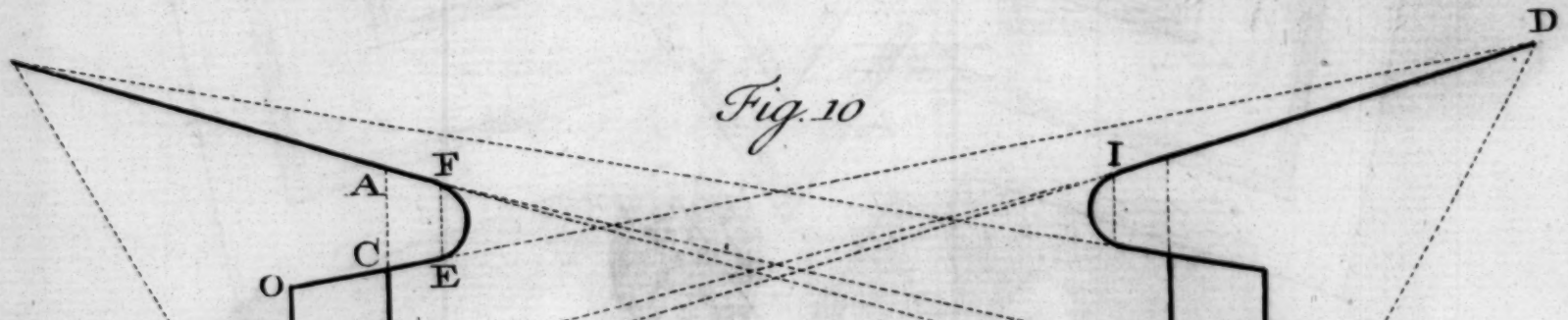


Fig. 10

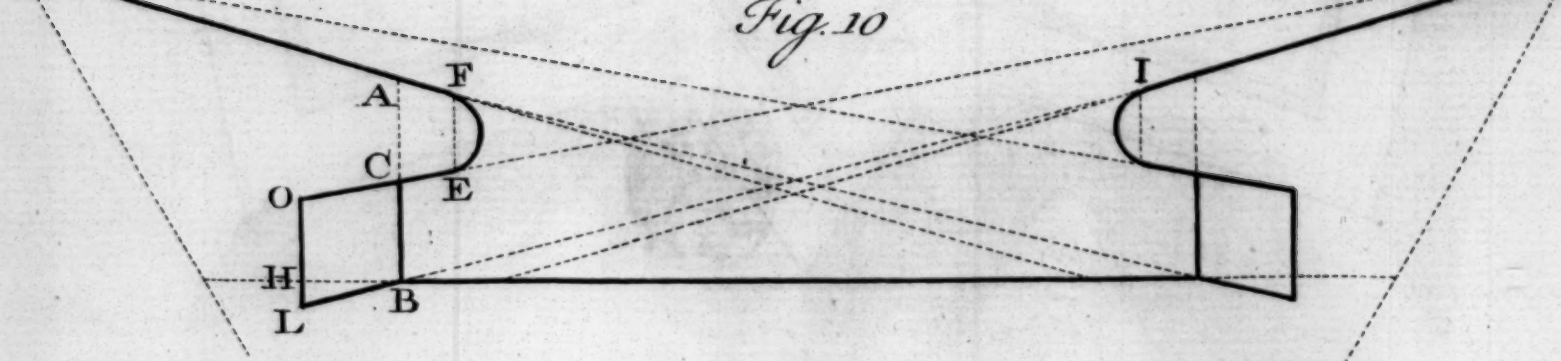


Fig. 10

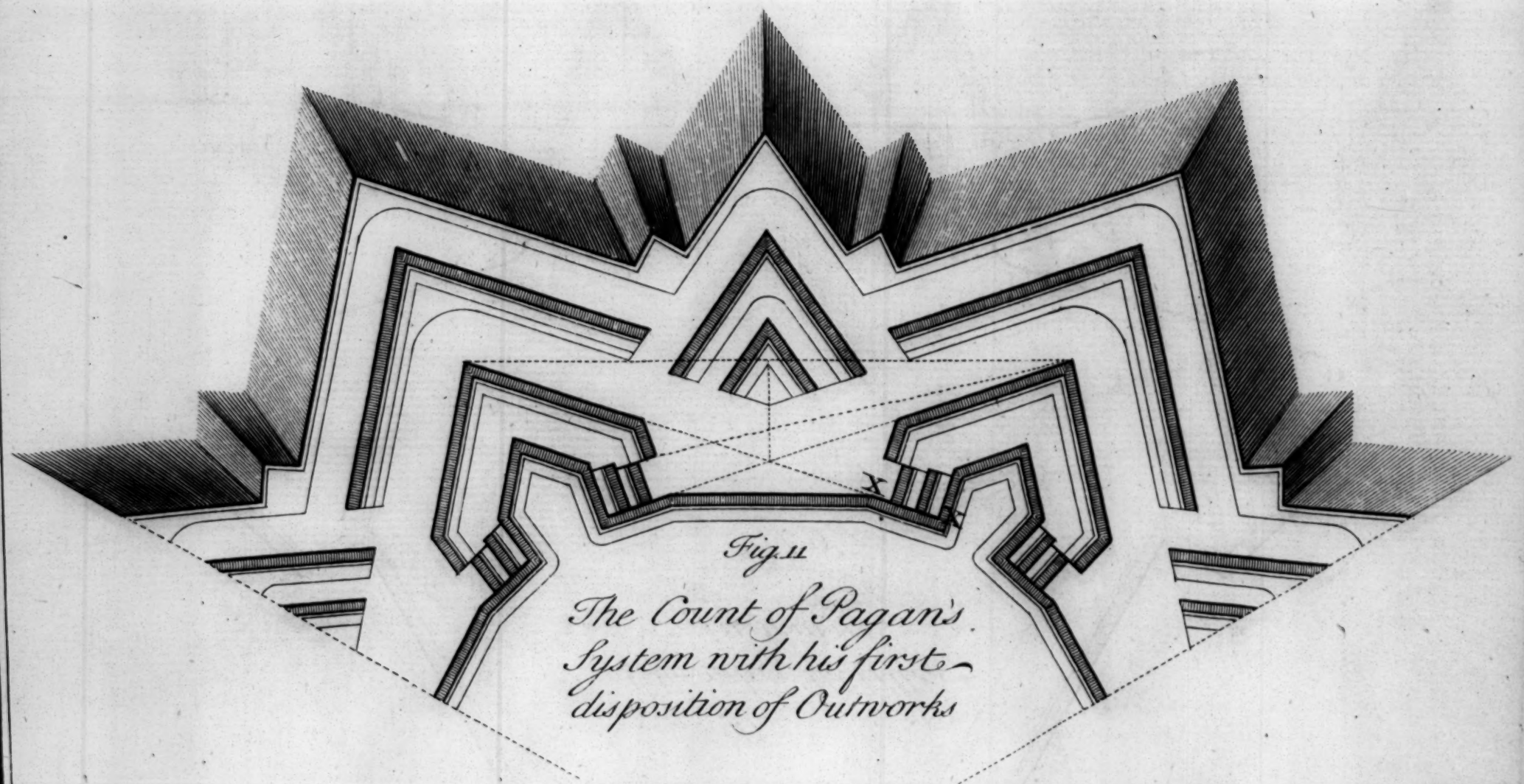


Fig. 11

The Count of Pagan's System with his first disposition of Outworks

Pla. 29

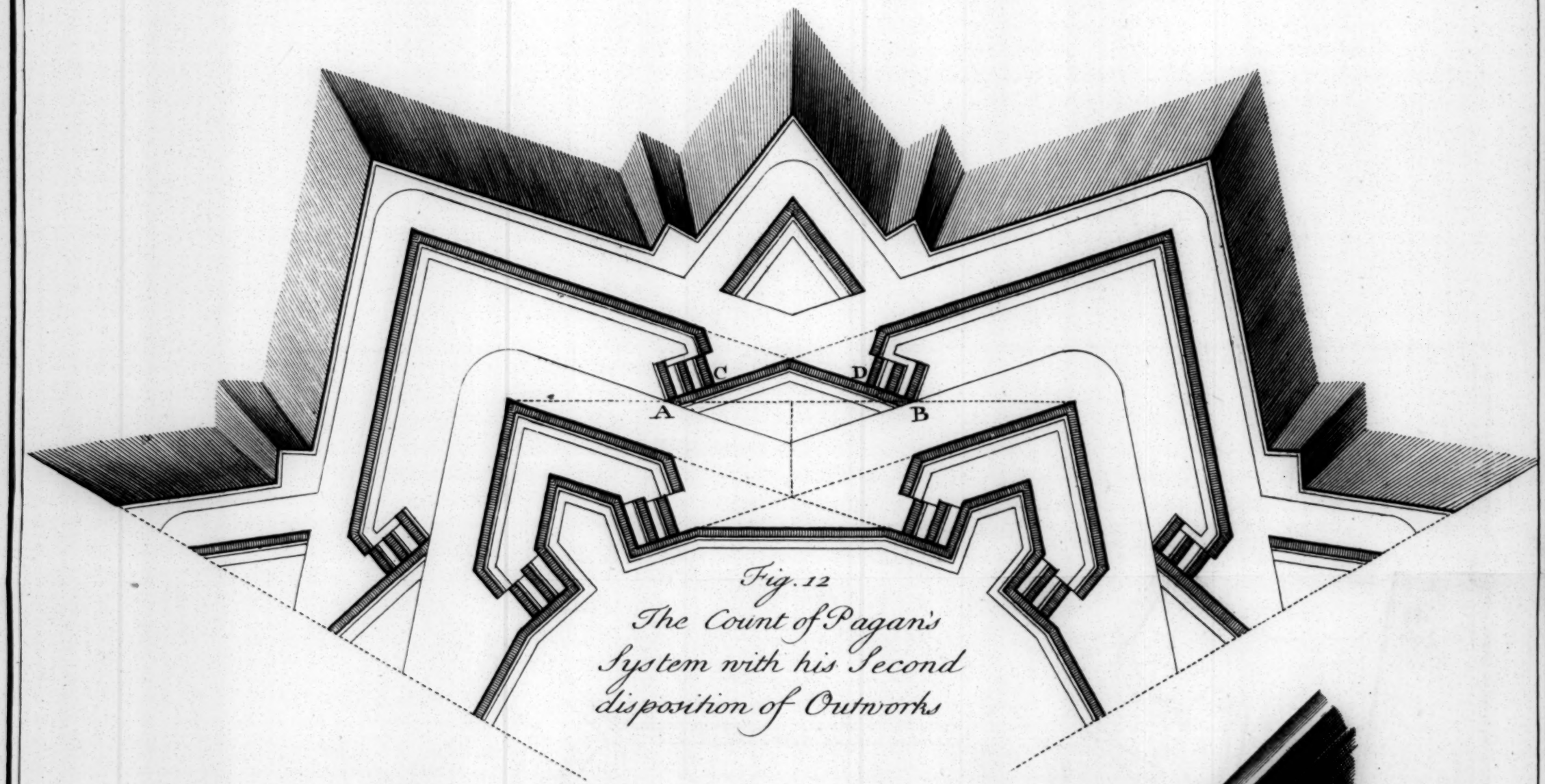
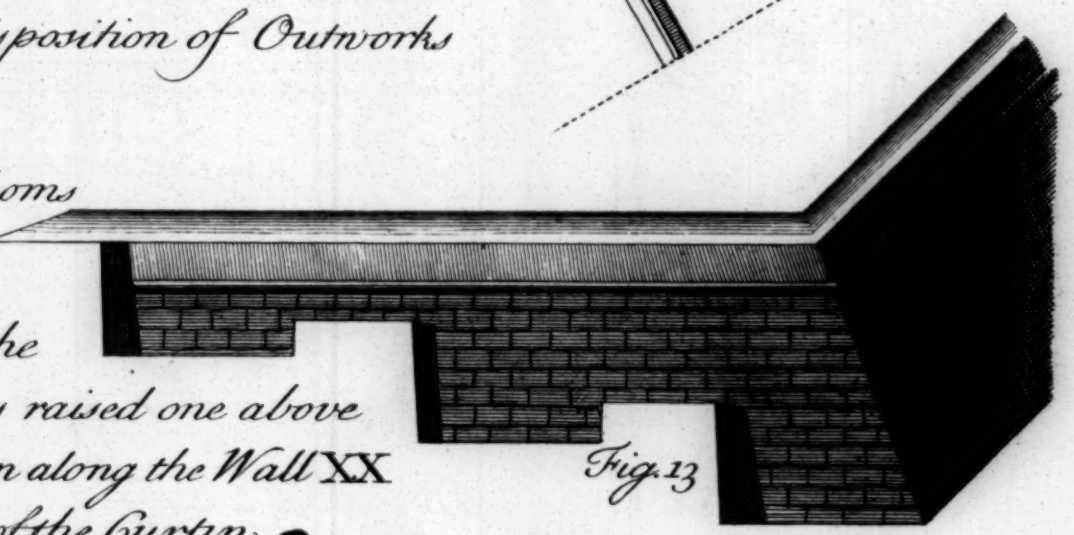


Fig. 12
The Count of Pagan's System with his Second disposition of Outworks

5 10 15 Fathoms



Profil of the three Batterics raised one above the Other taken along the Wall XX of the Retreat of the Curtan

Fig. 13

the Other taken along the Wall XX
of the Retreat of the Curtain

Fig. 13

N.B. y.y.y Shews the figure of the half Moon with its flanked Angle as fixed by the Author

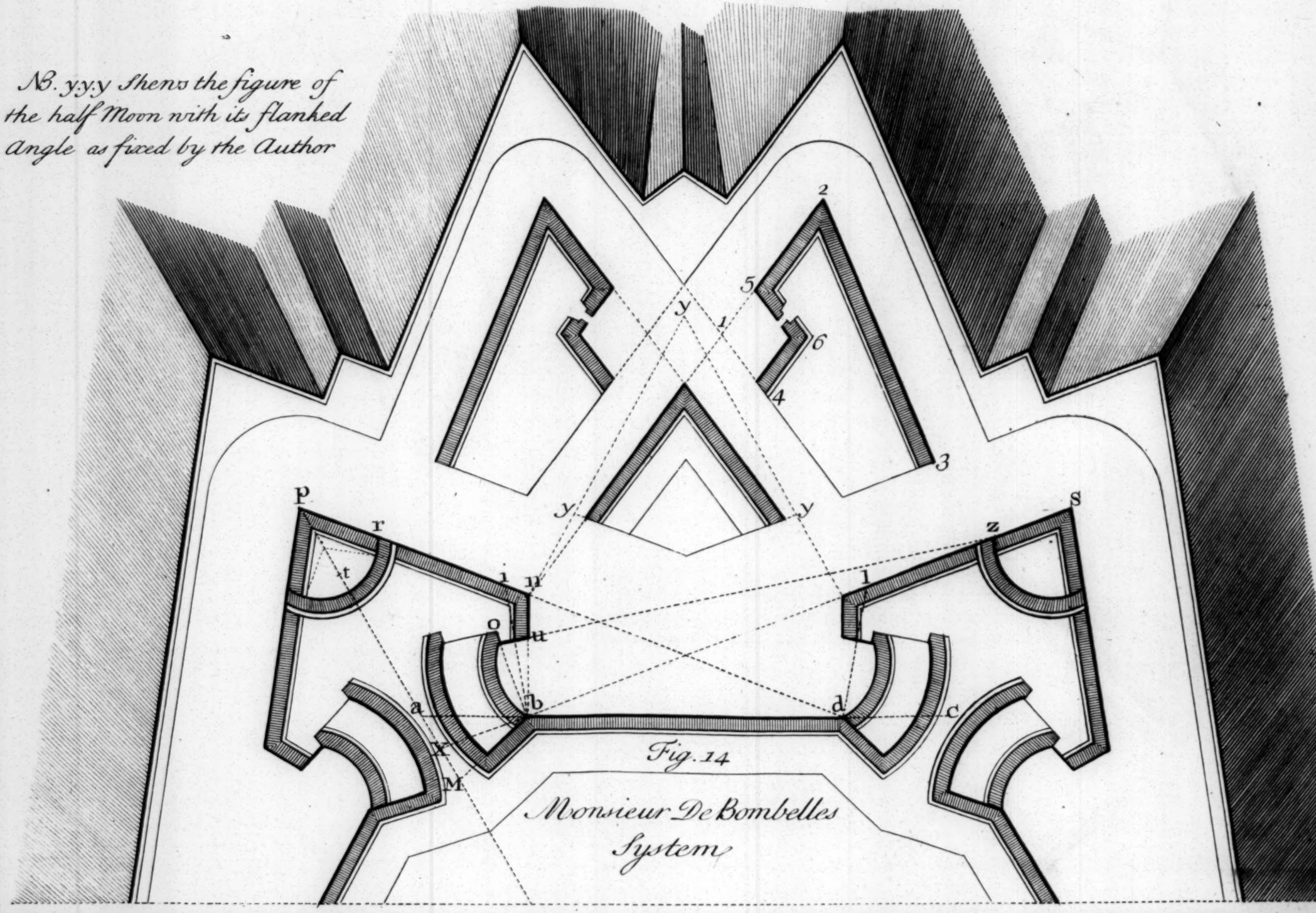
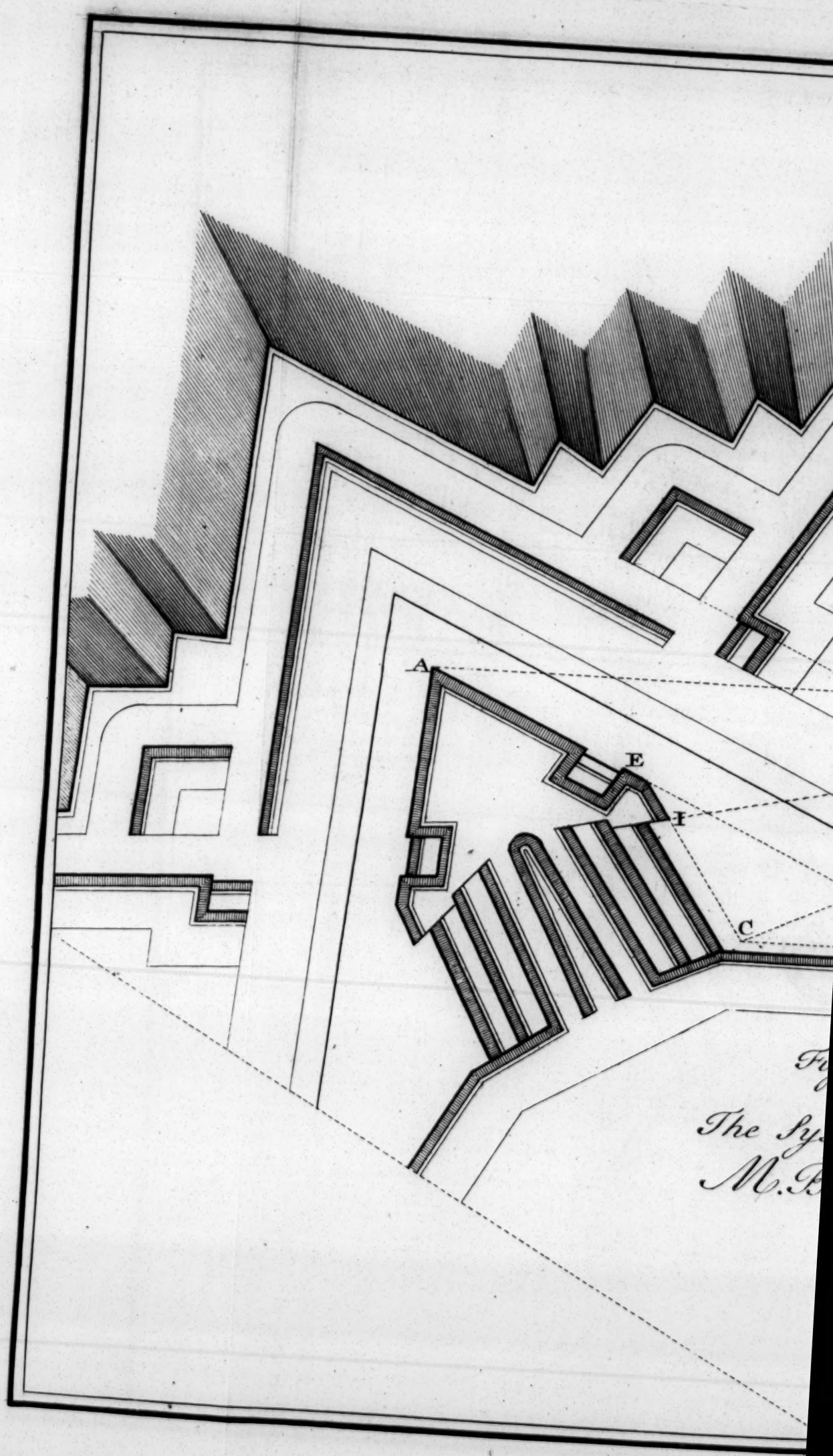


Fig. 14

Monsieur De Bombelles
System

Pla. 30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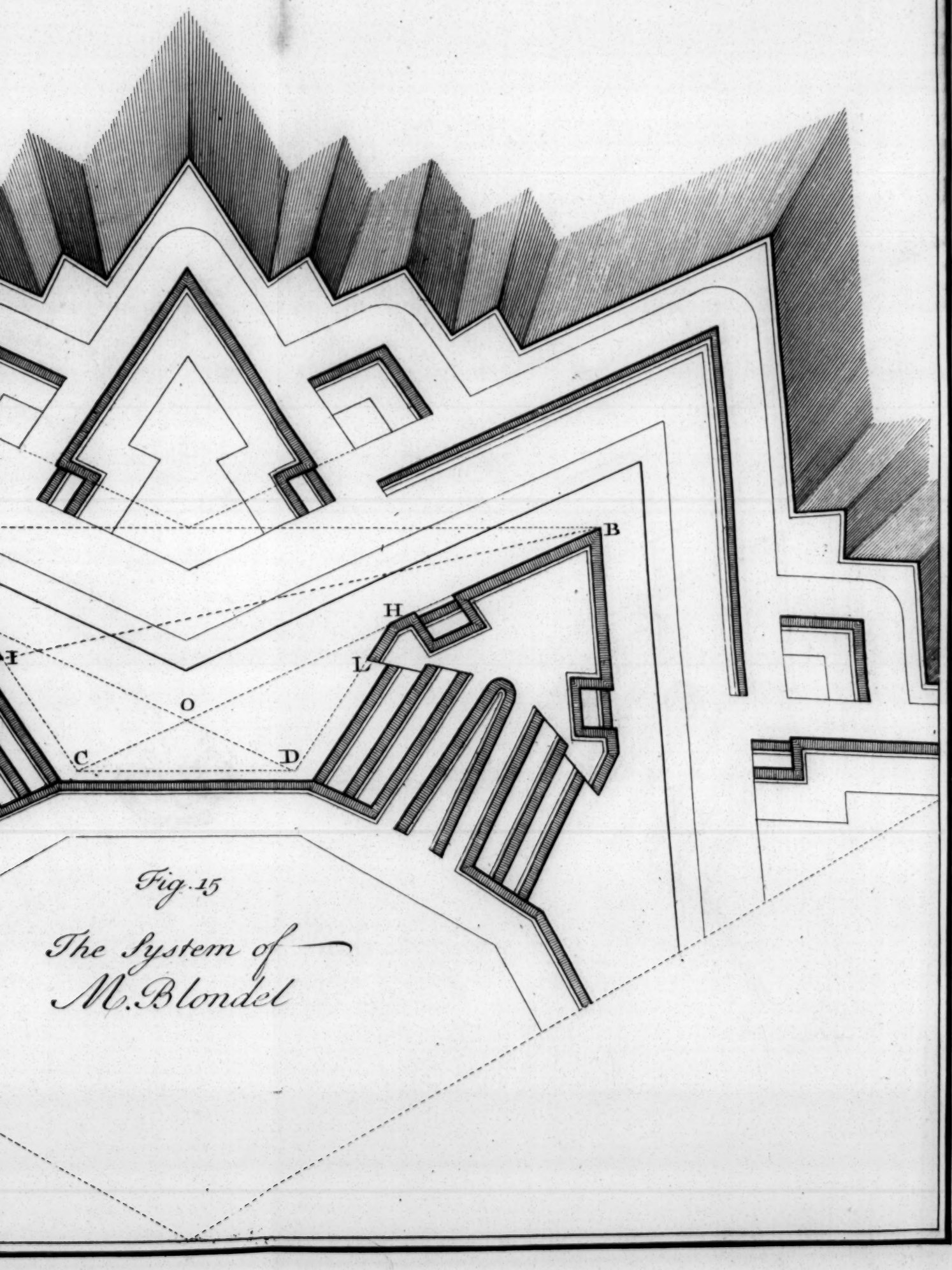
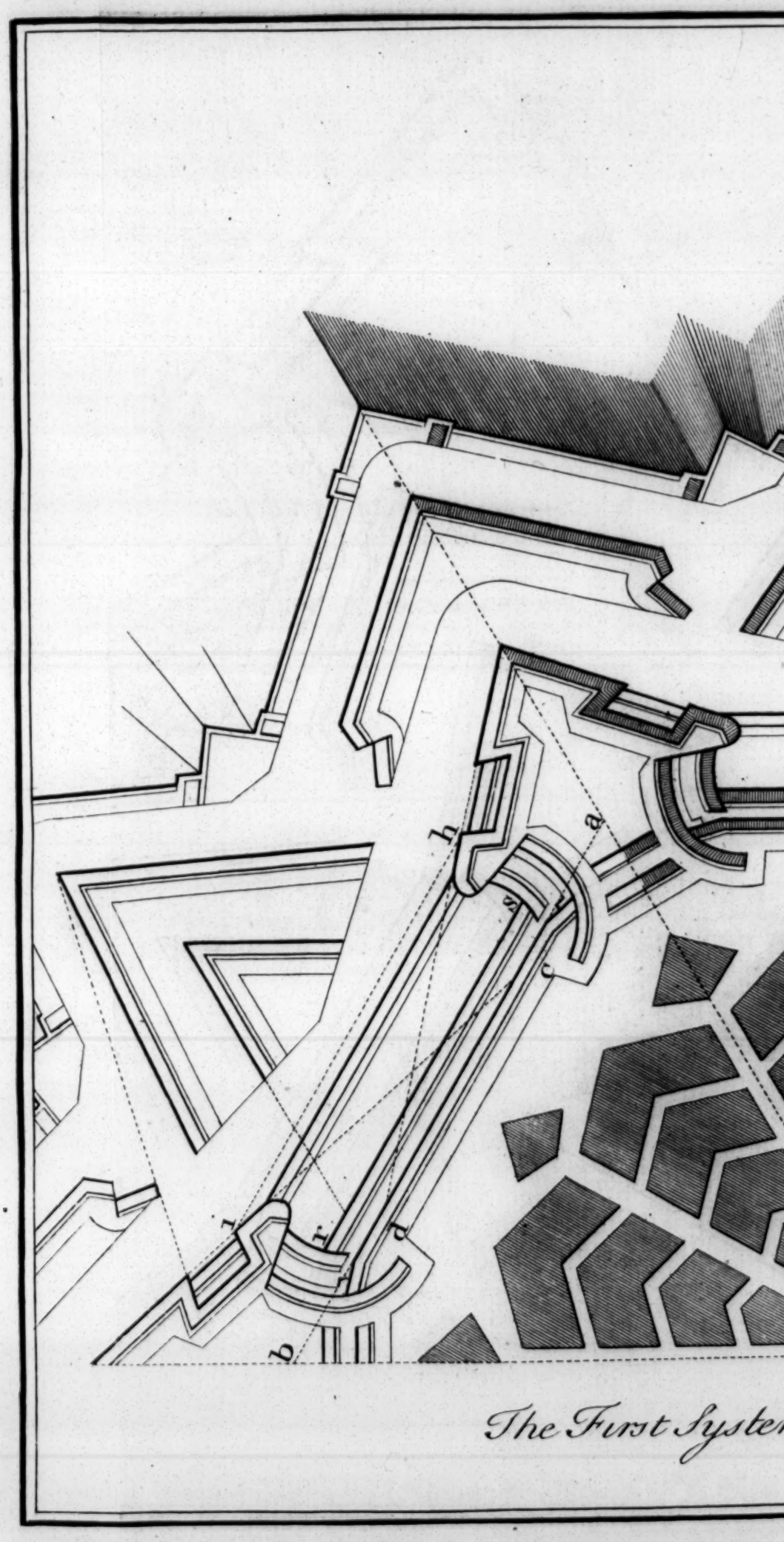


Fig. 15

The System of
M. Blondel



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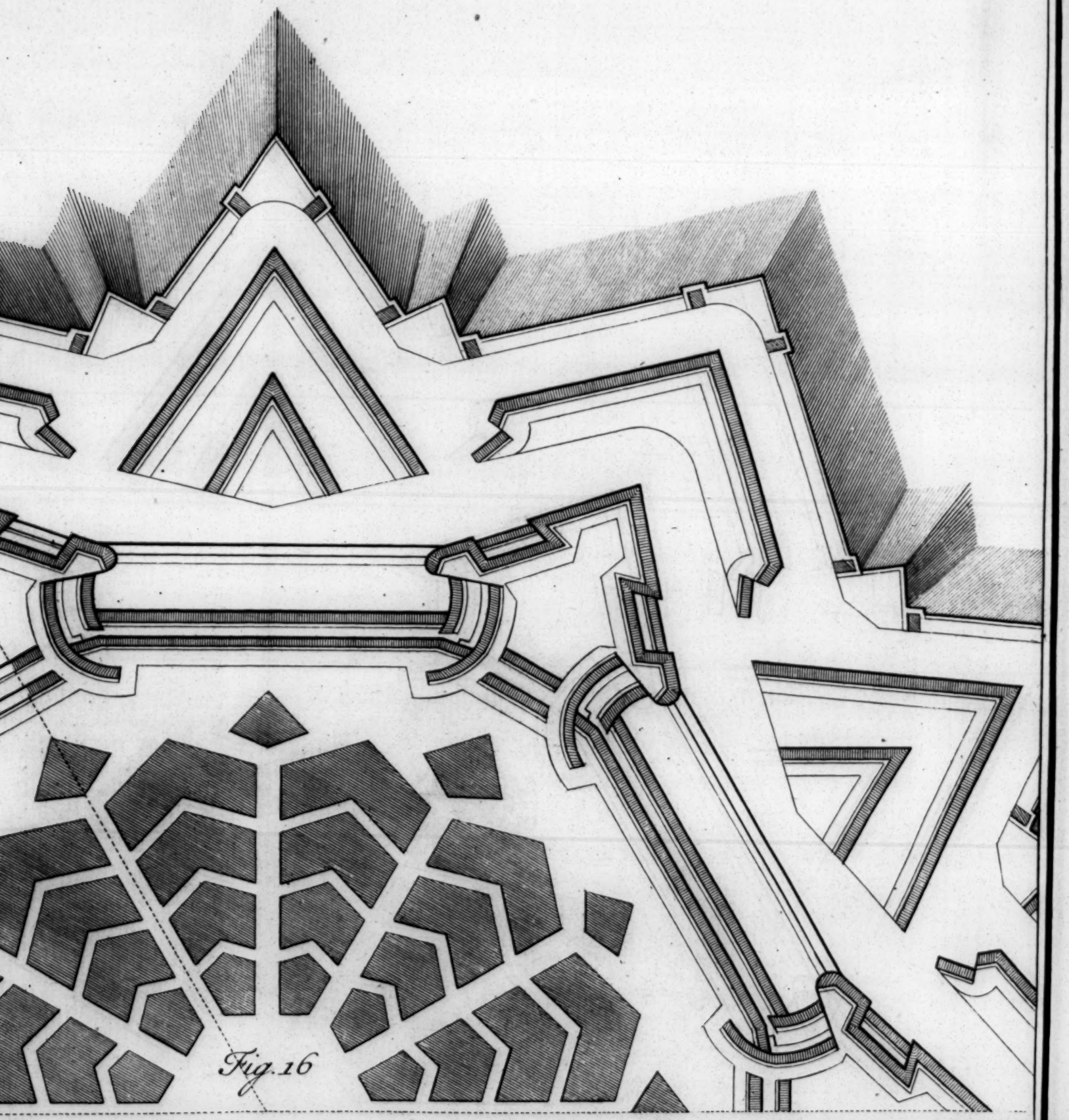

Fig. 16

rst System of an Anonymous Author

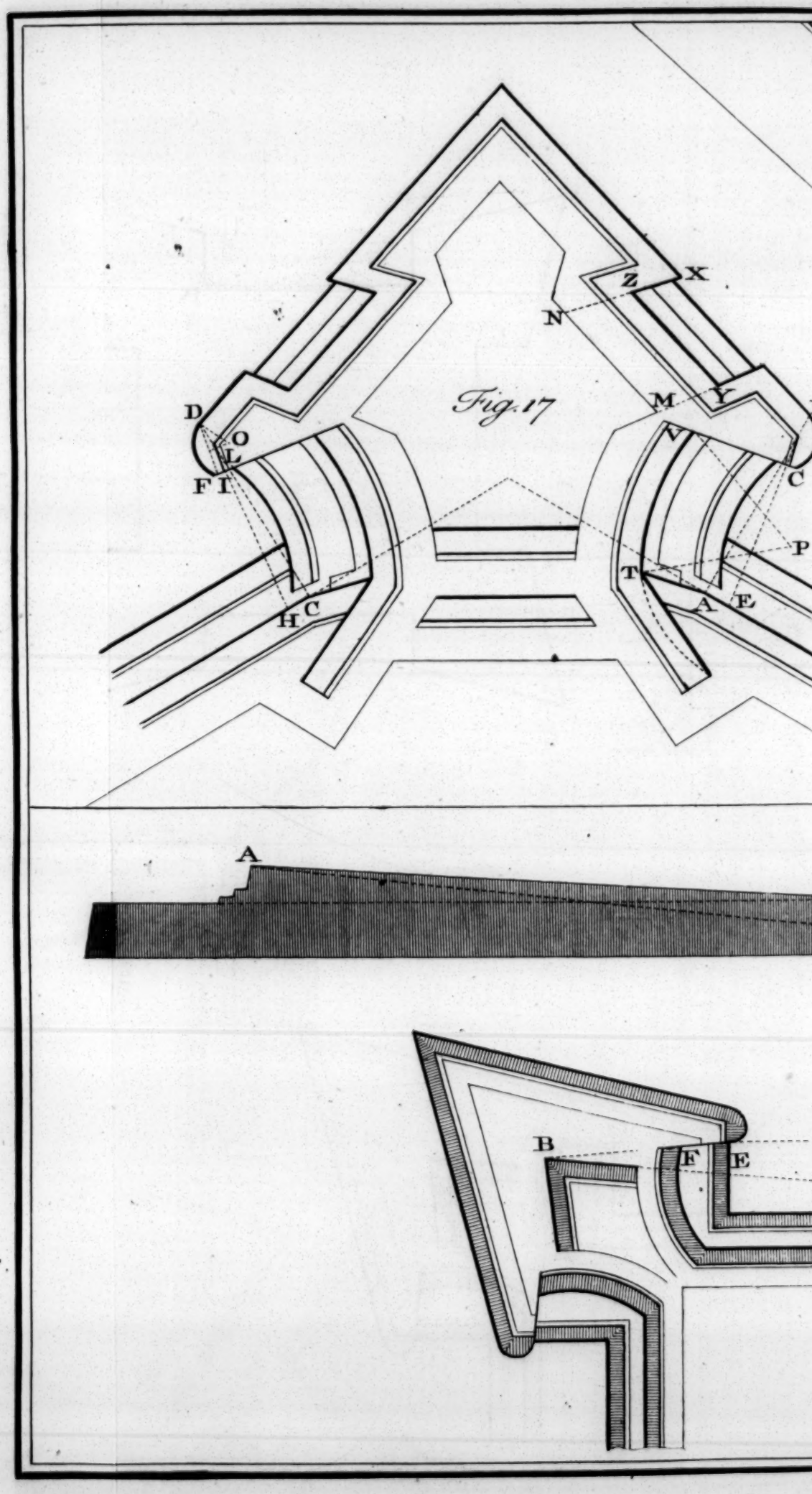
Fig. 17
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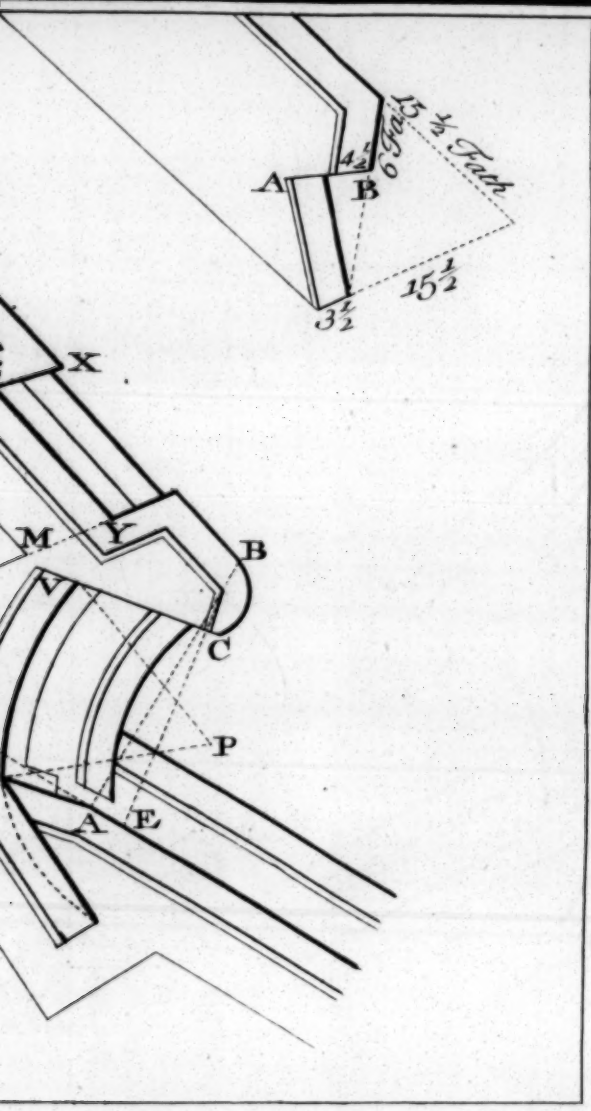


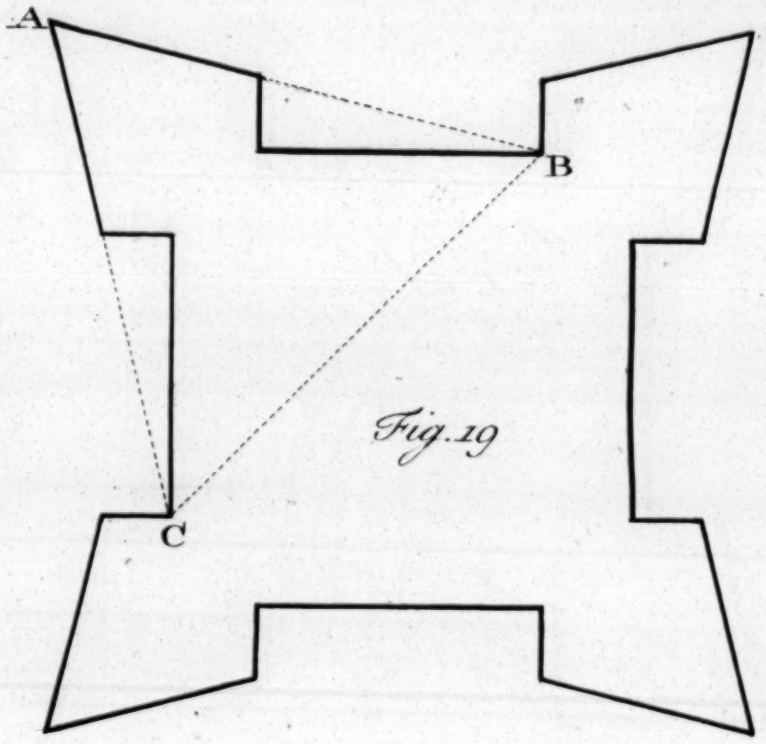


Fig. 19

Fig. 18

Fig. 20

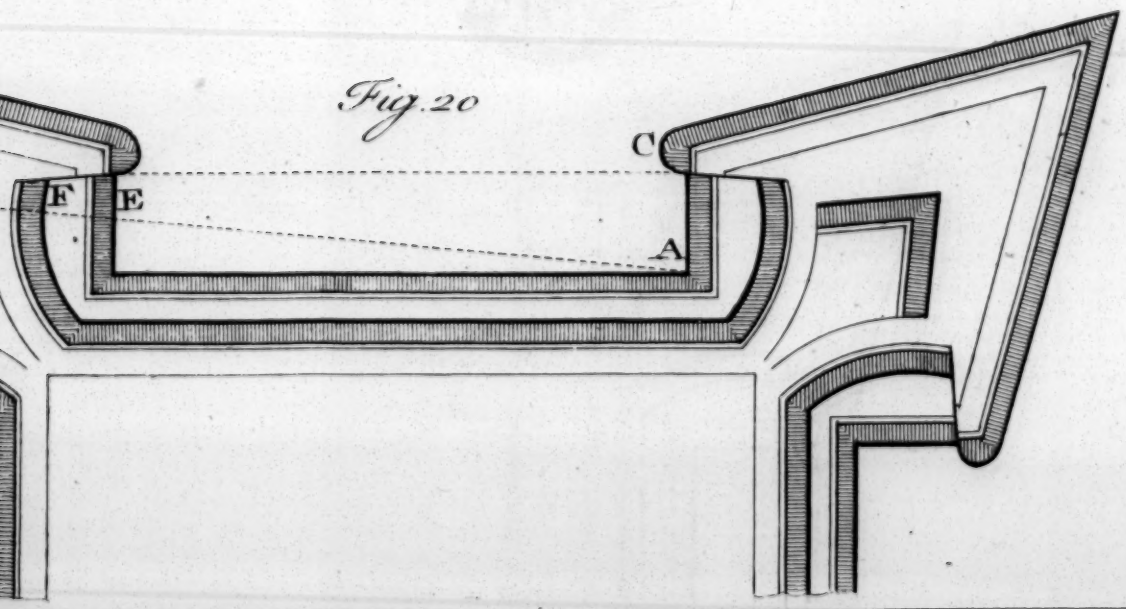
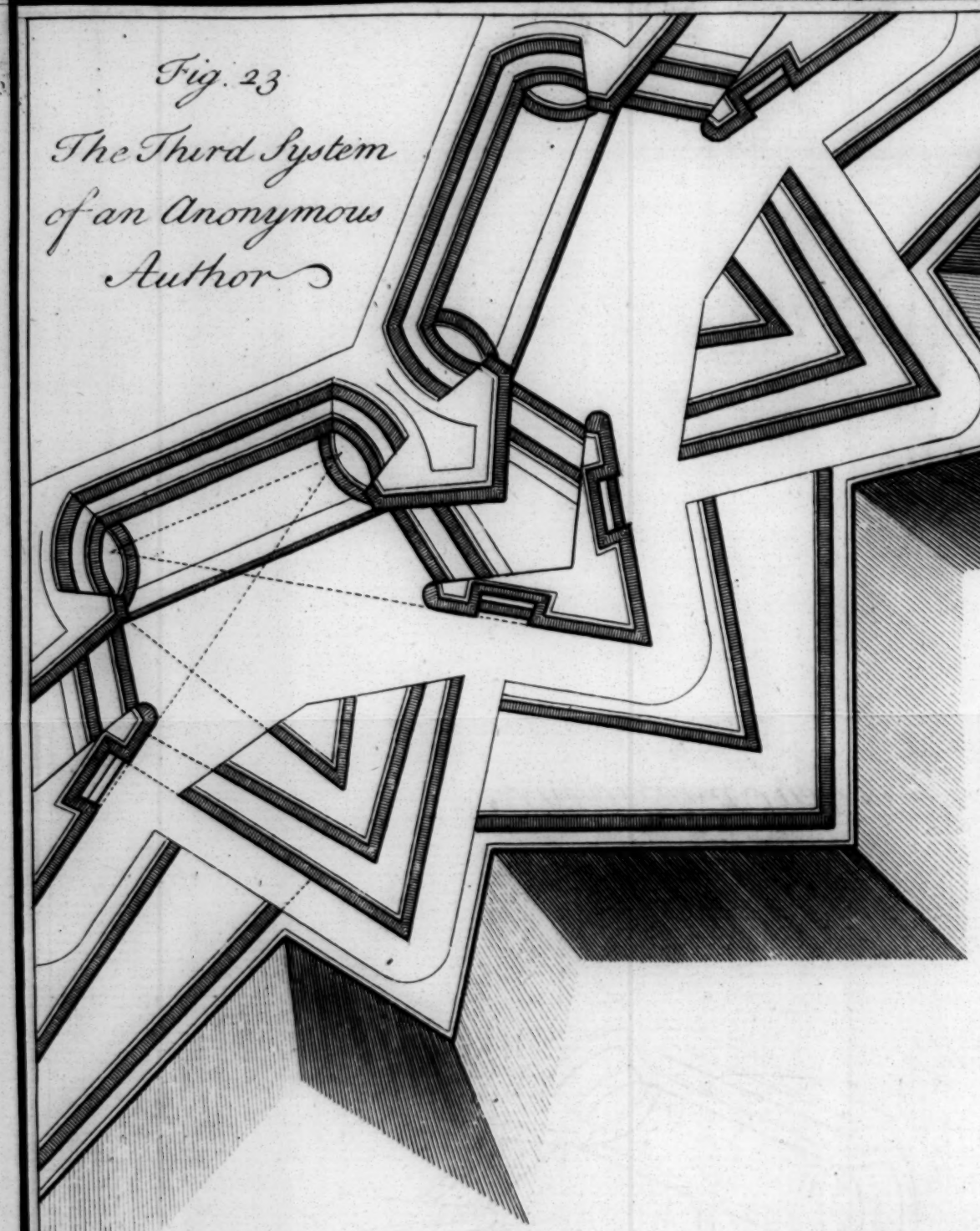


Fig. 23

The Third System of an Anonymous Author



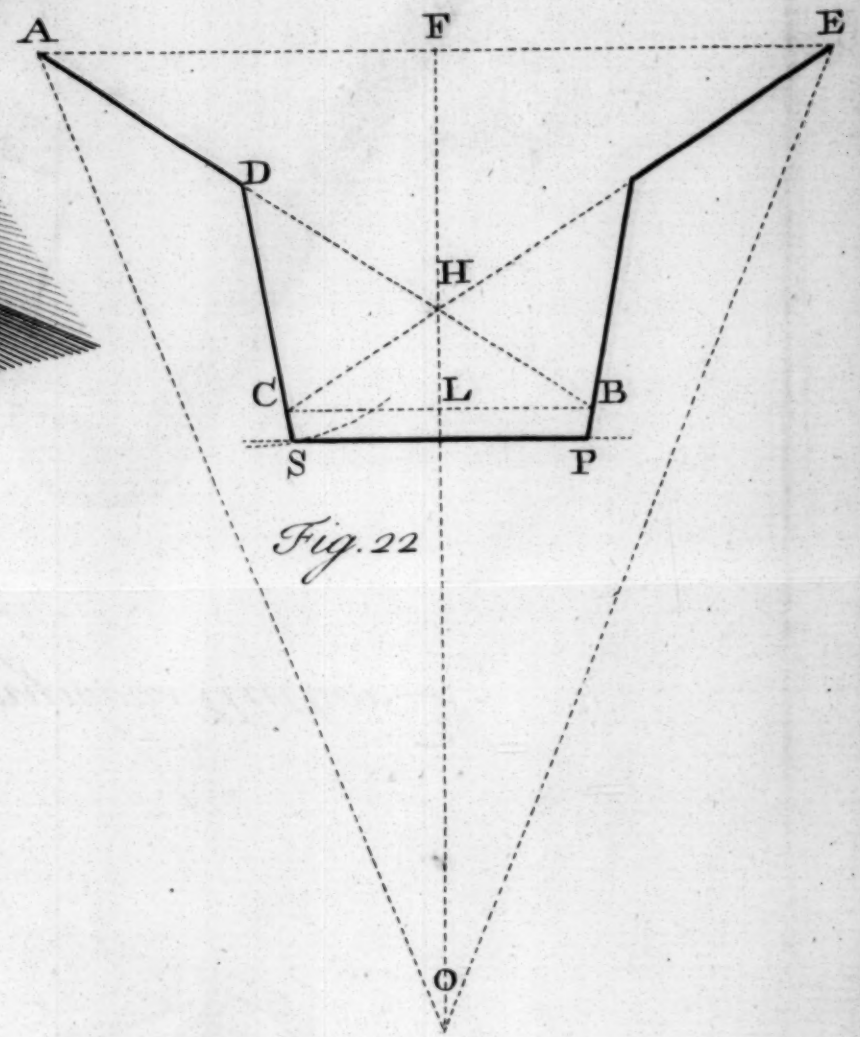


Fig. 22

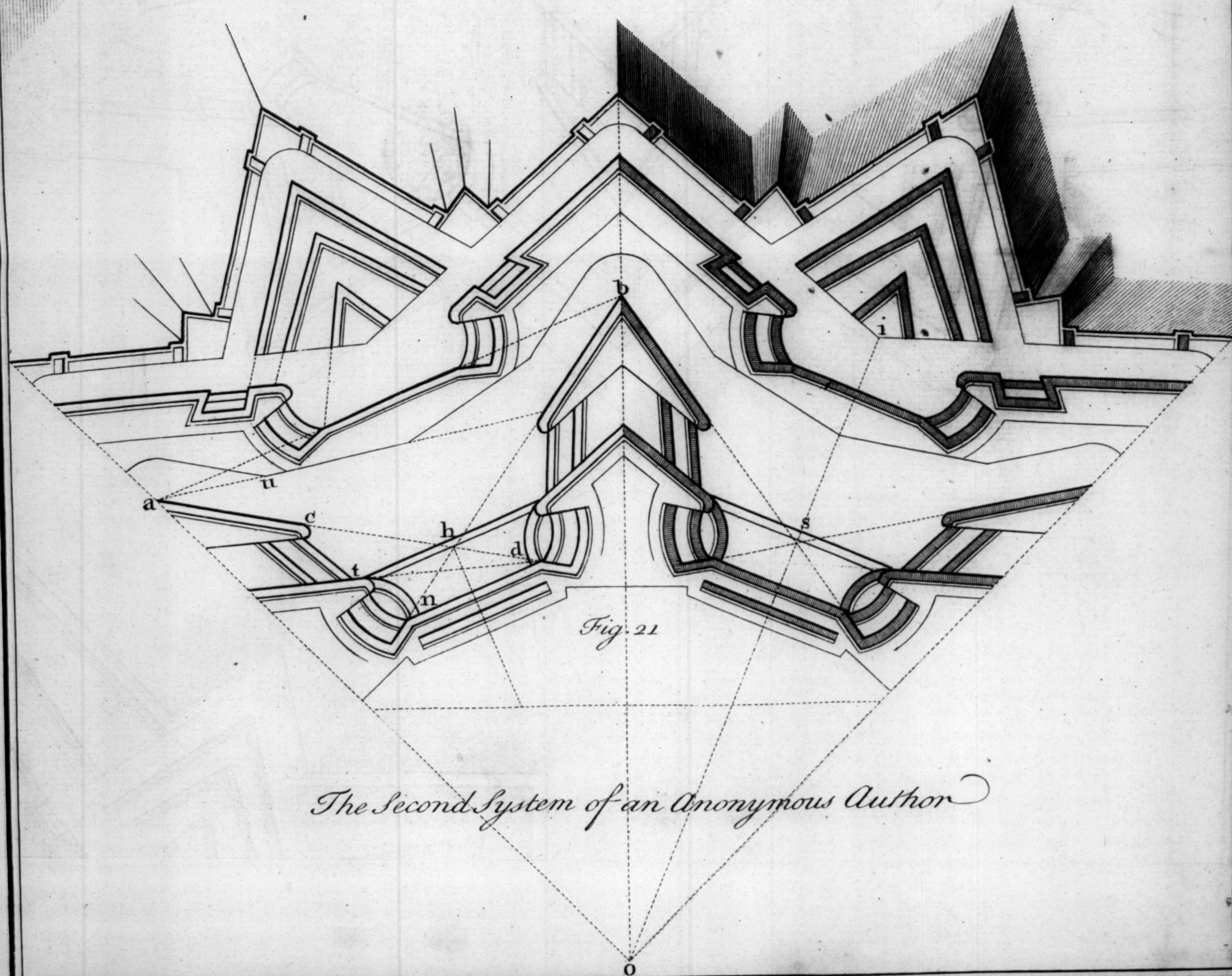
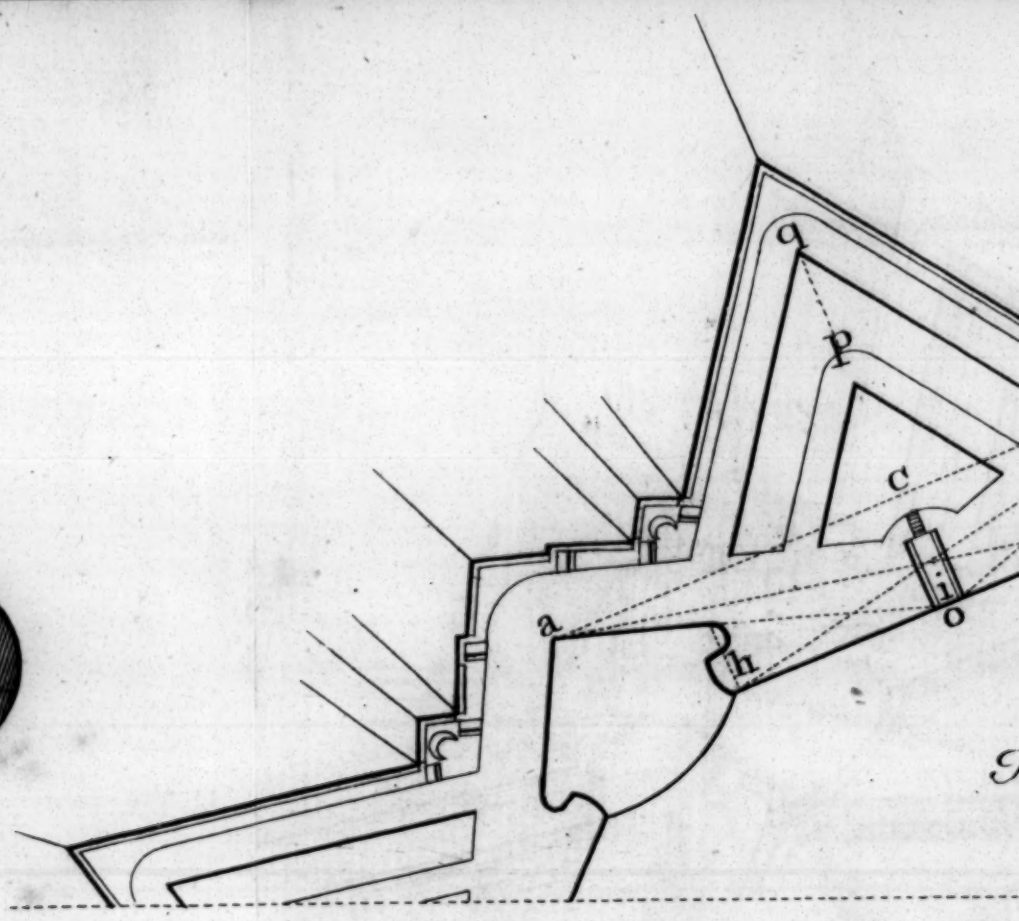
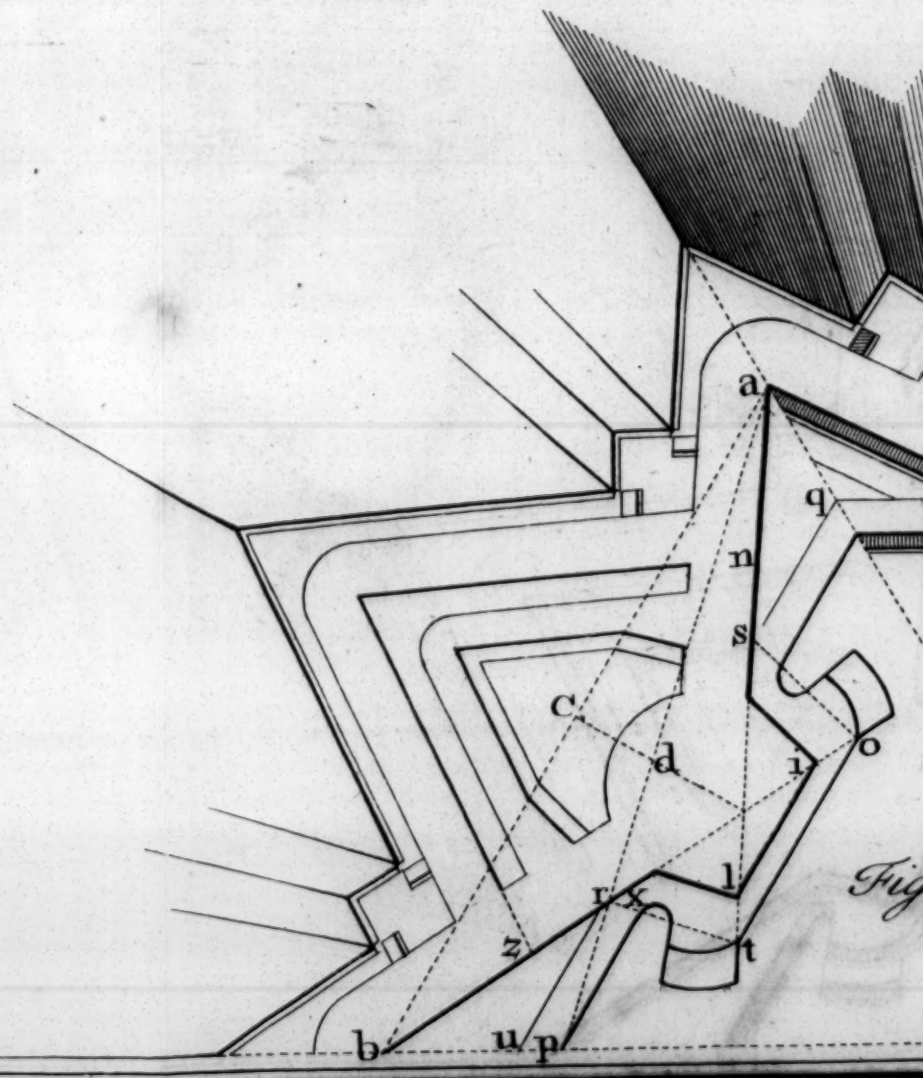


Fig. 21

The Second System of an Anonymous Author

Fig.25





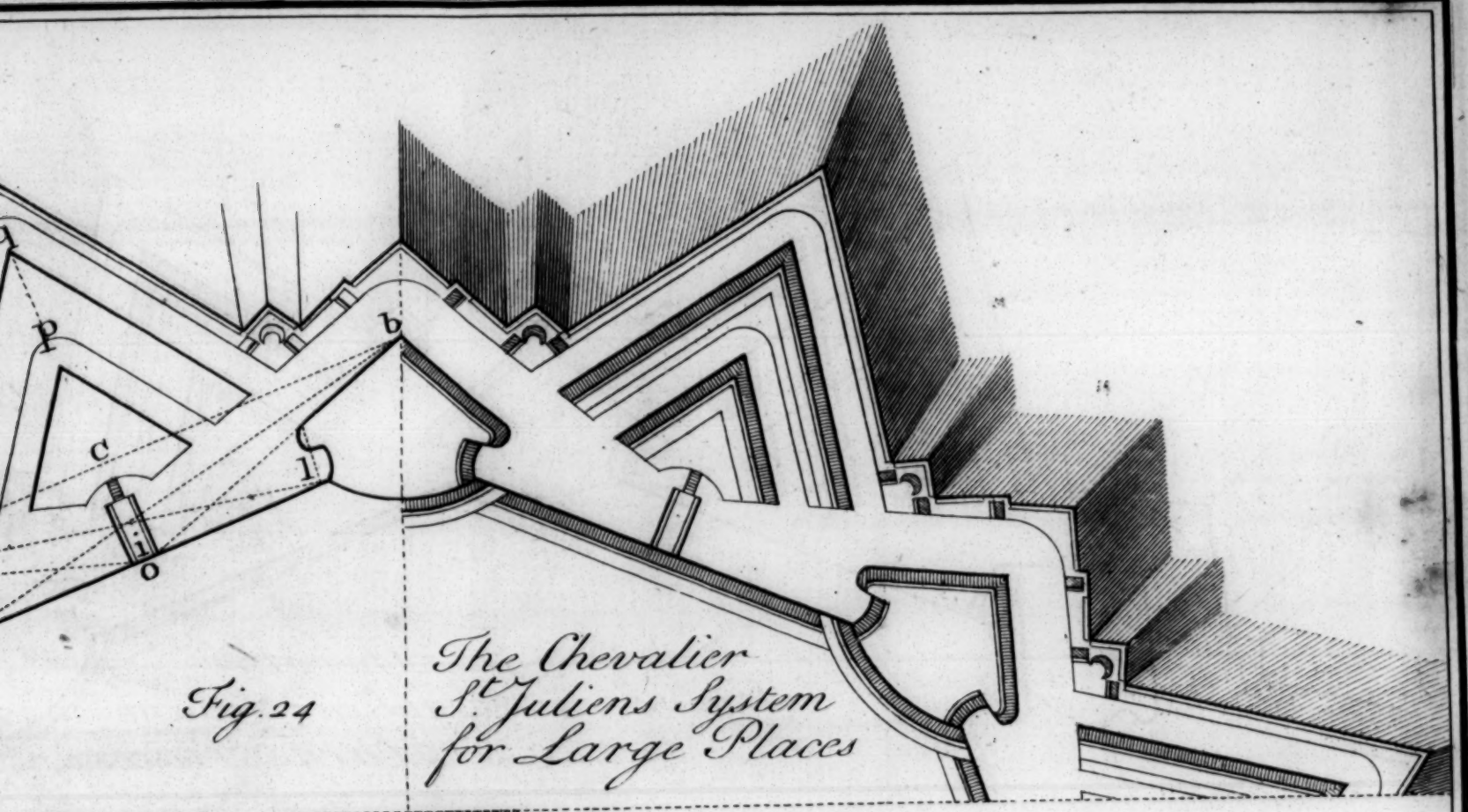


Fig. 24

The Chevalier
St. Juliens System
for Large Places

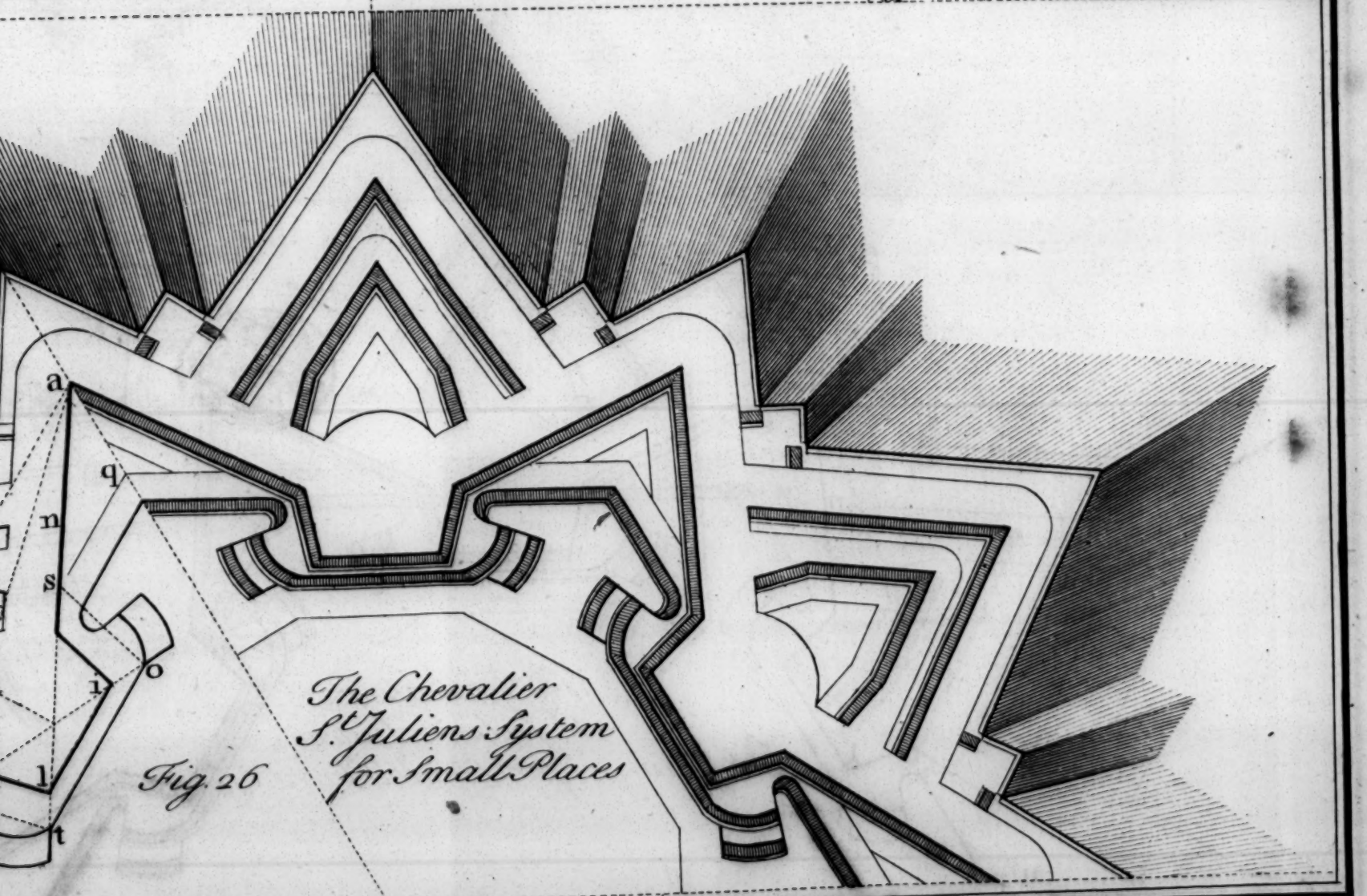
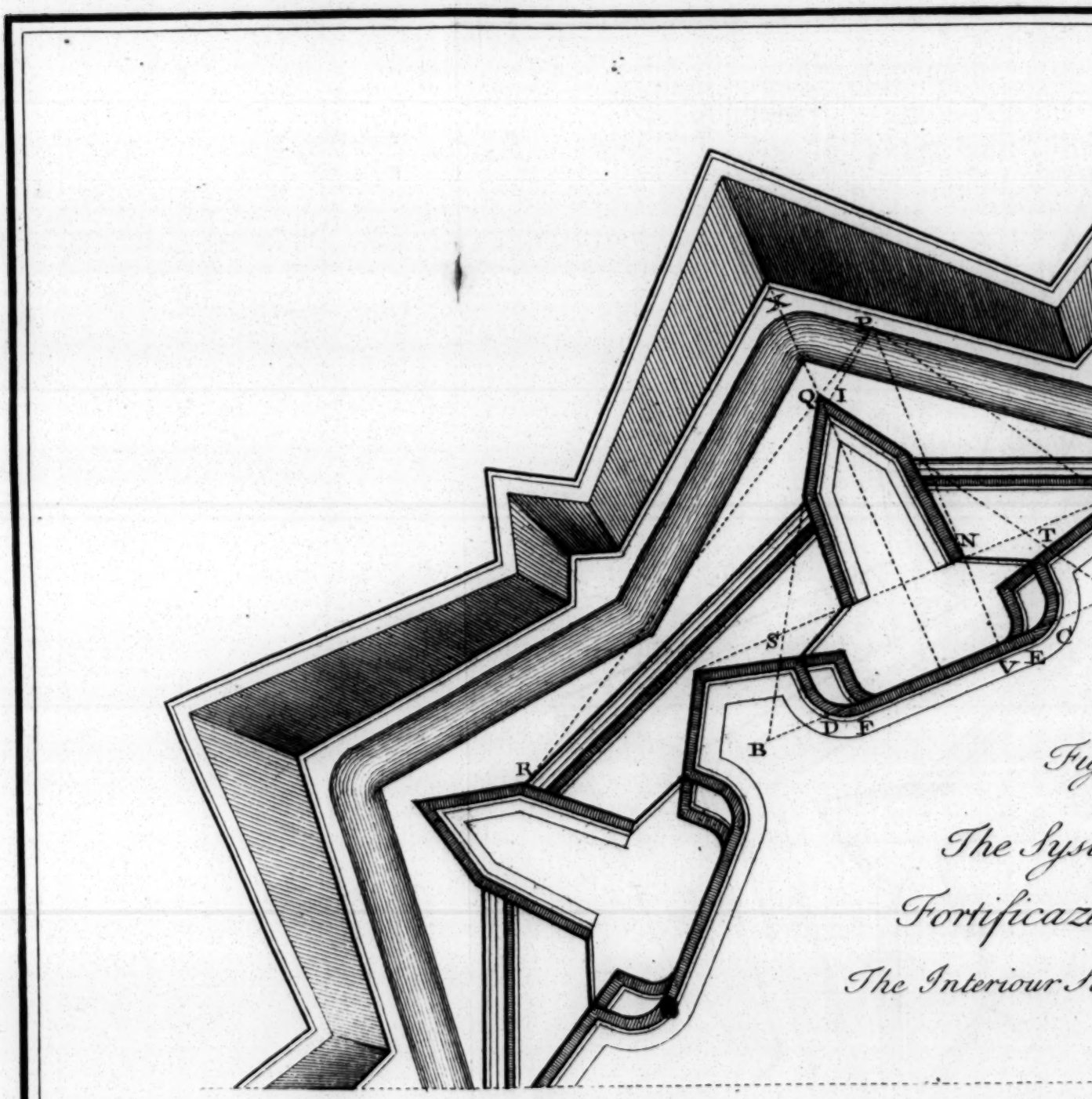


Fig. 26

The Chevalier
St. Juliens System
for Small Places



Fig

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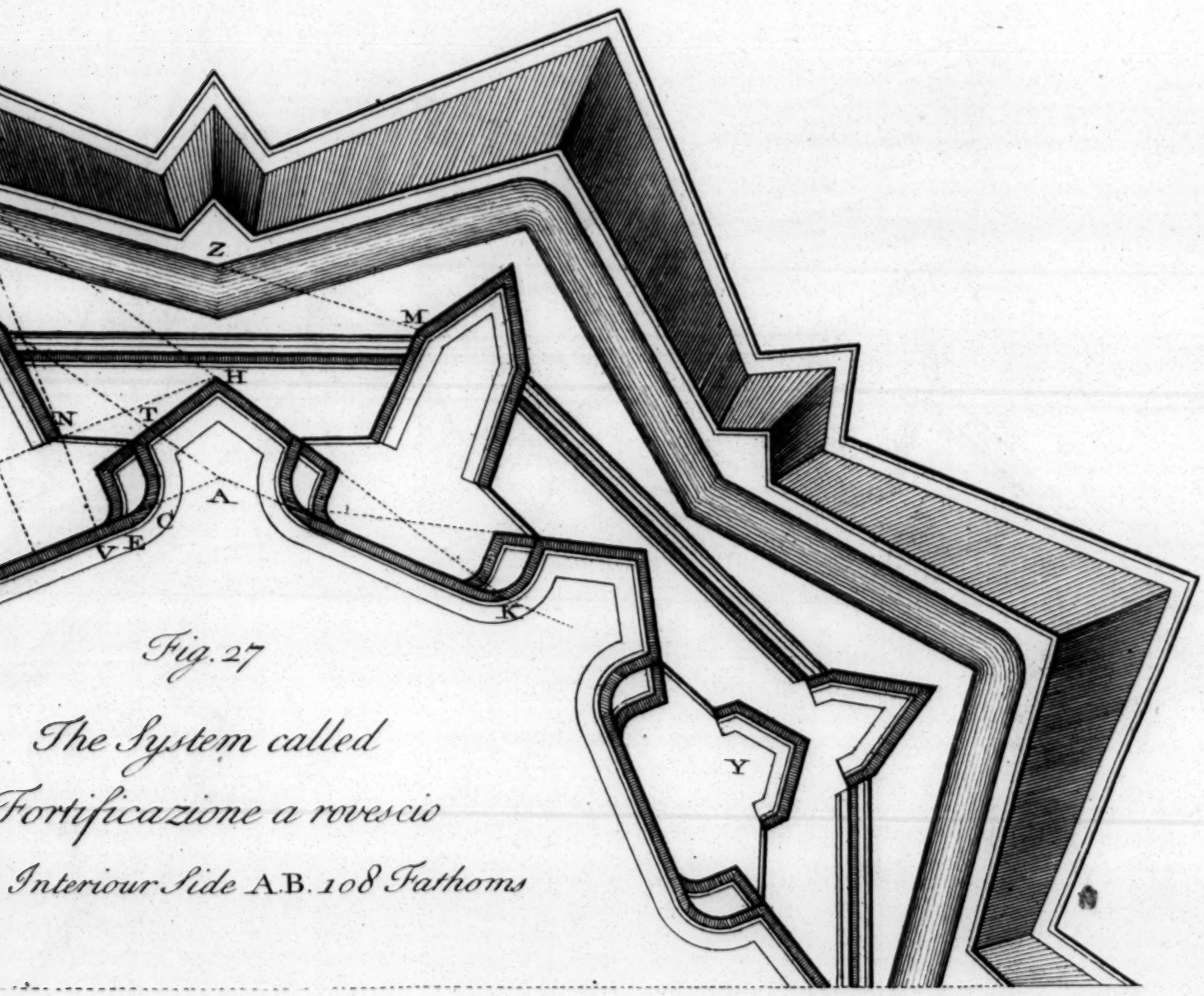
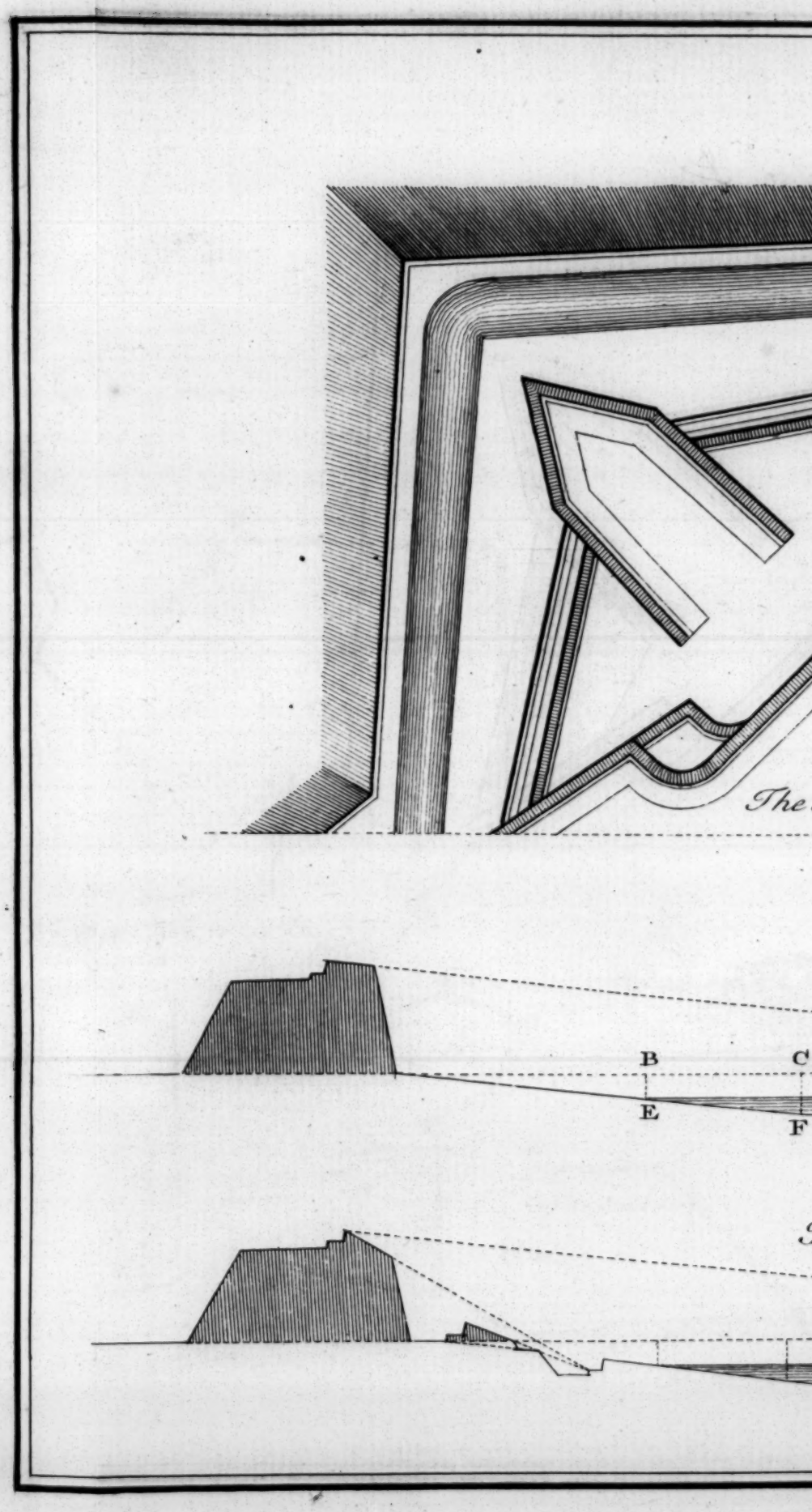


Fig. 27

The System called
Fortificazione a rovescio
Interiour Side A.B. *108 Fathoms*


B
C
E
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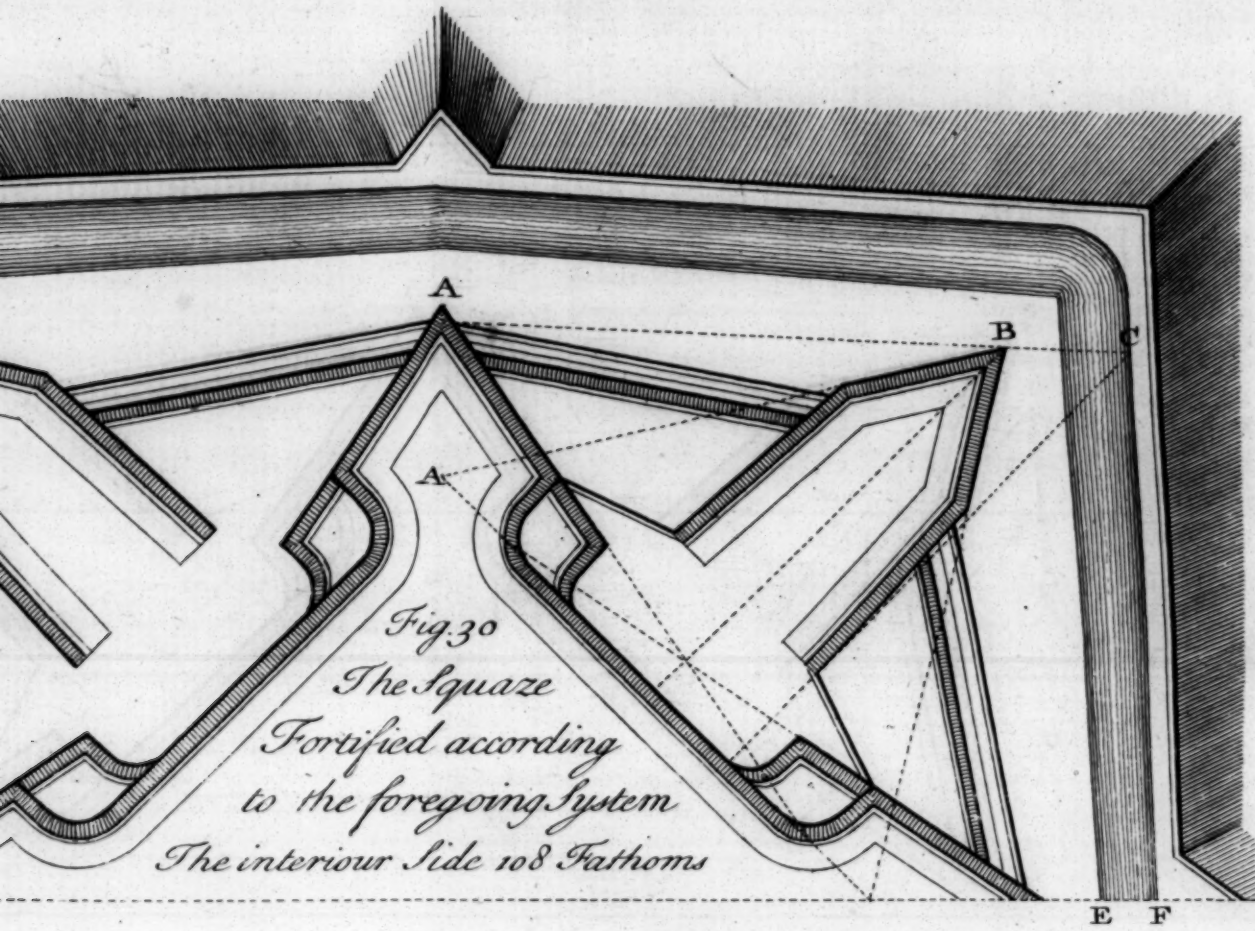


Fig. 30
The Squaze
Fortified according
to the foregoing System
The interiour Side 108 Fathoms

Fig. 28

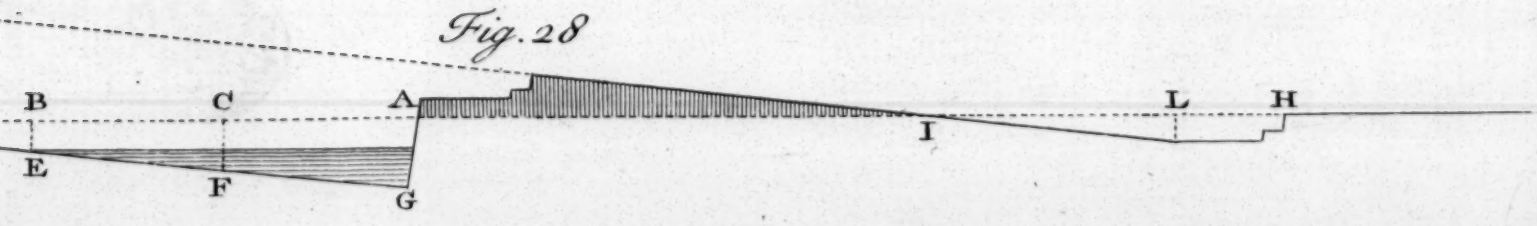
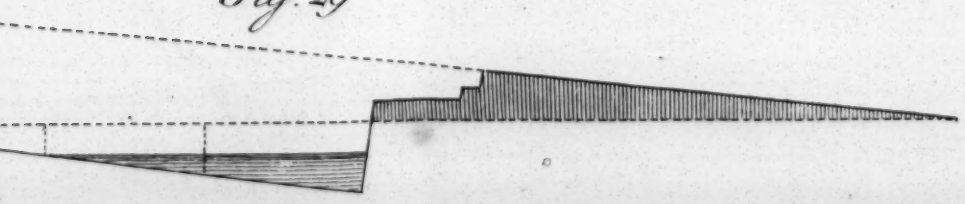


Fig. 29



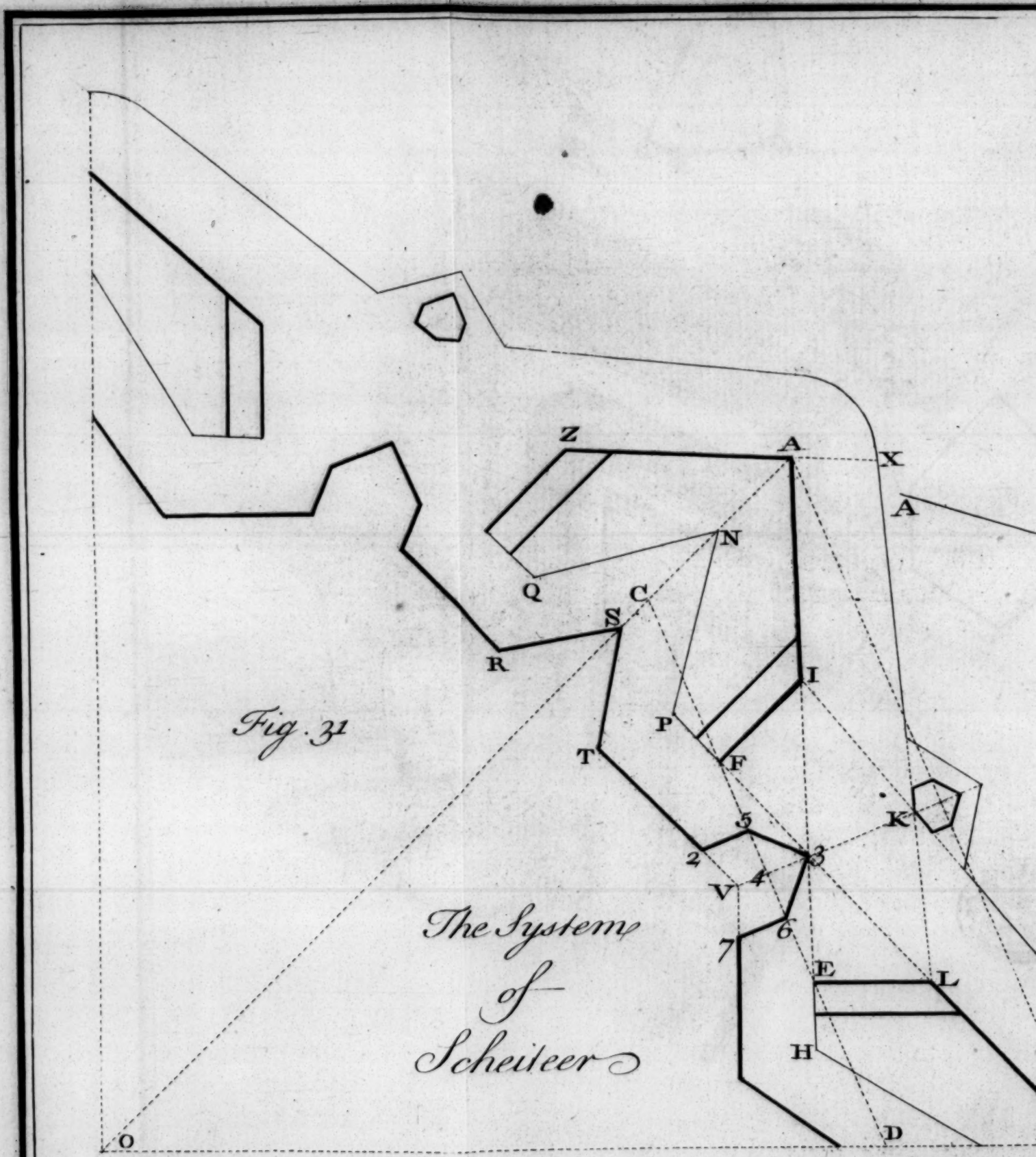


Fig. 31

The System of Scheiteer

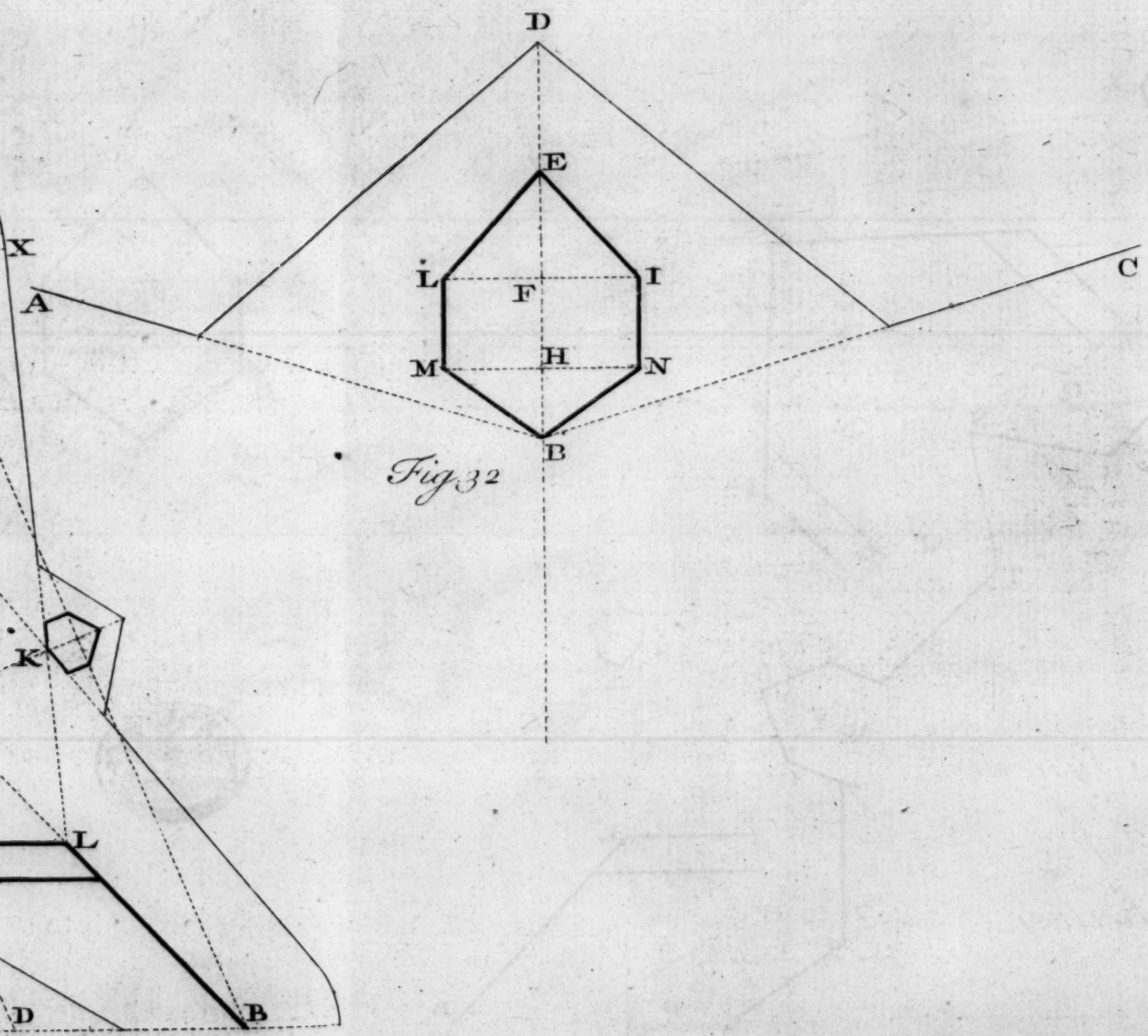
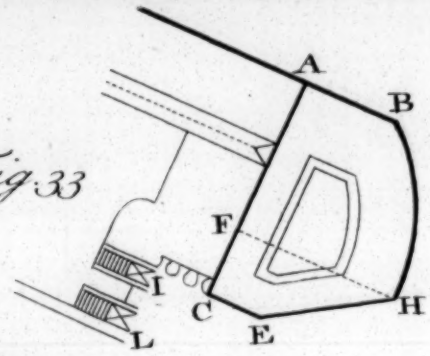
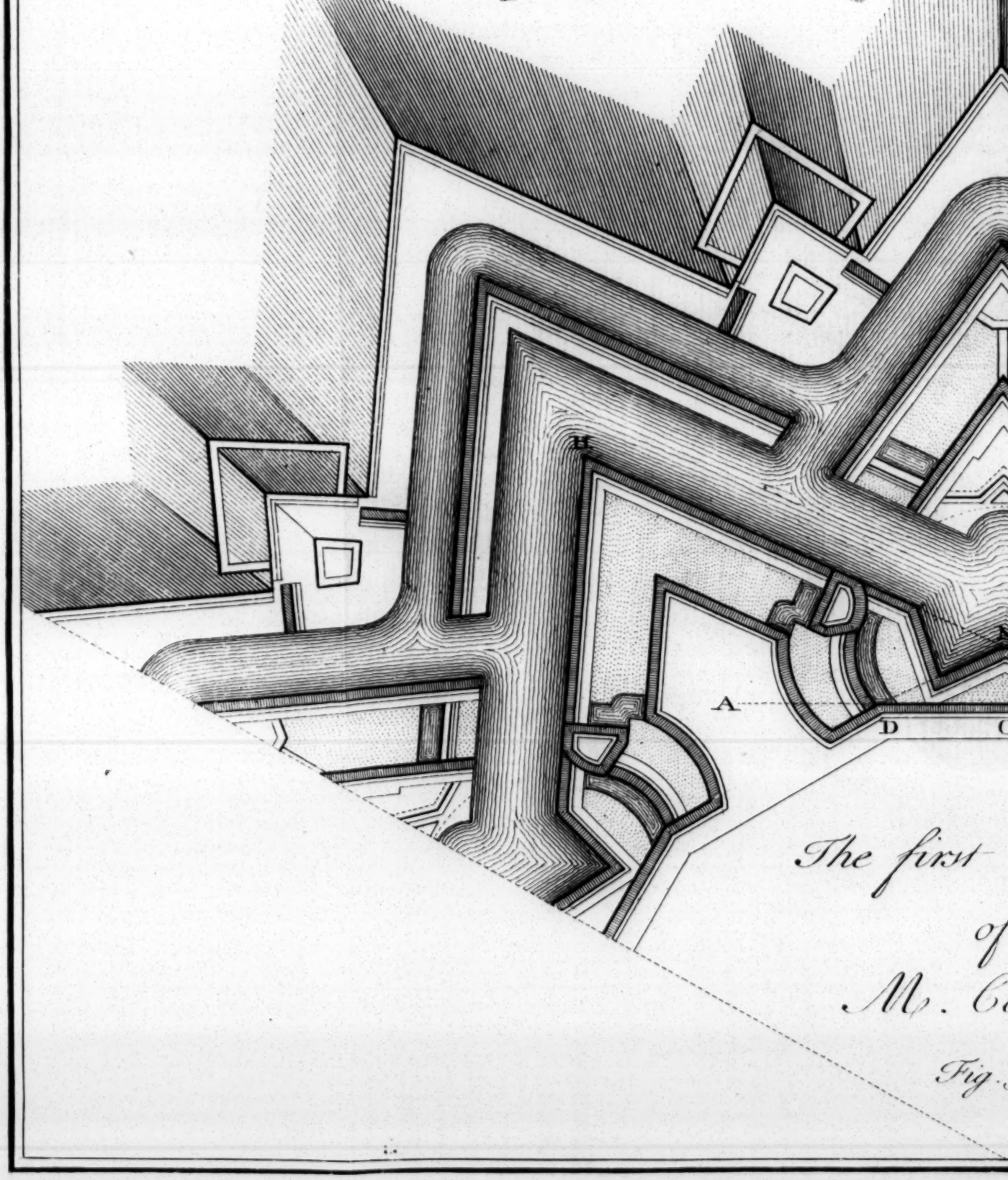


Fig. 32

Fig. 33





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of

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Fig.

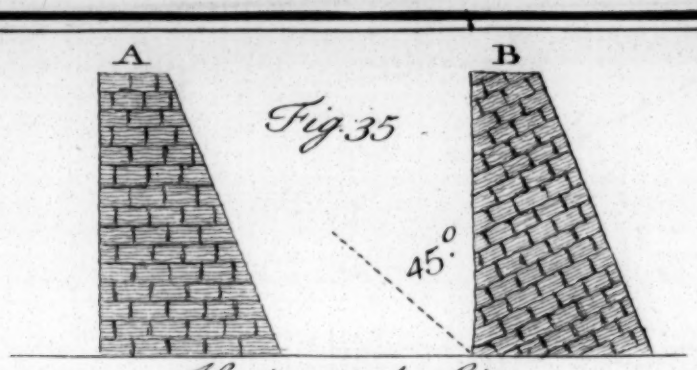
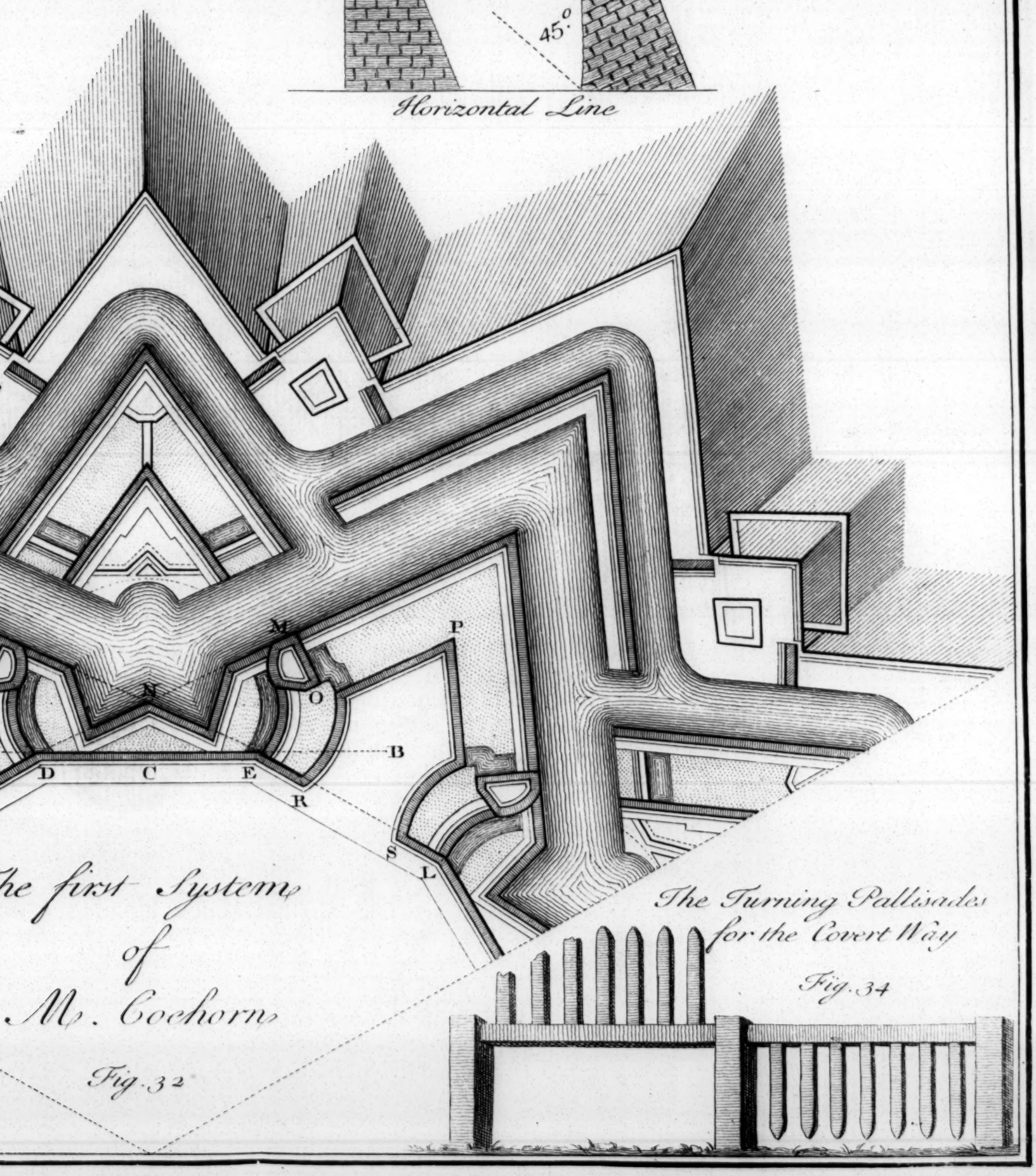


Fig. 35

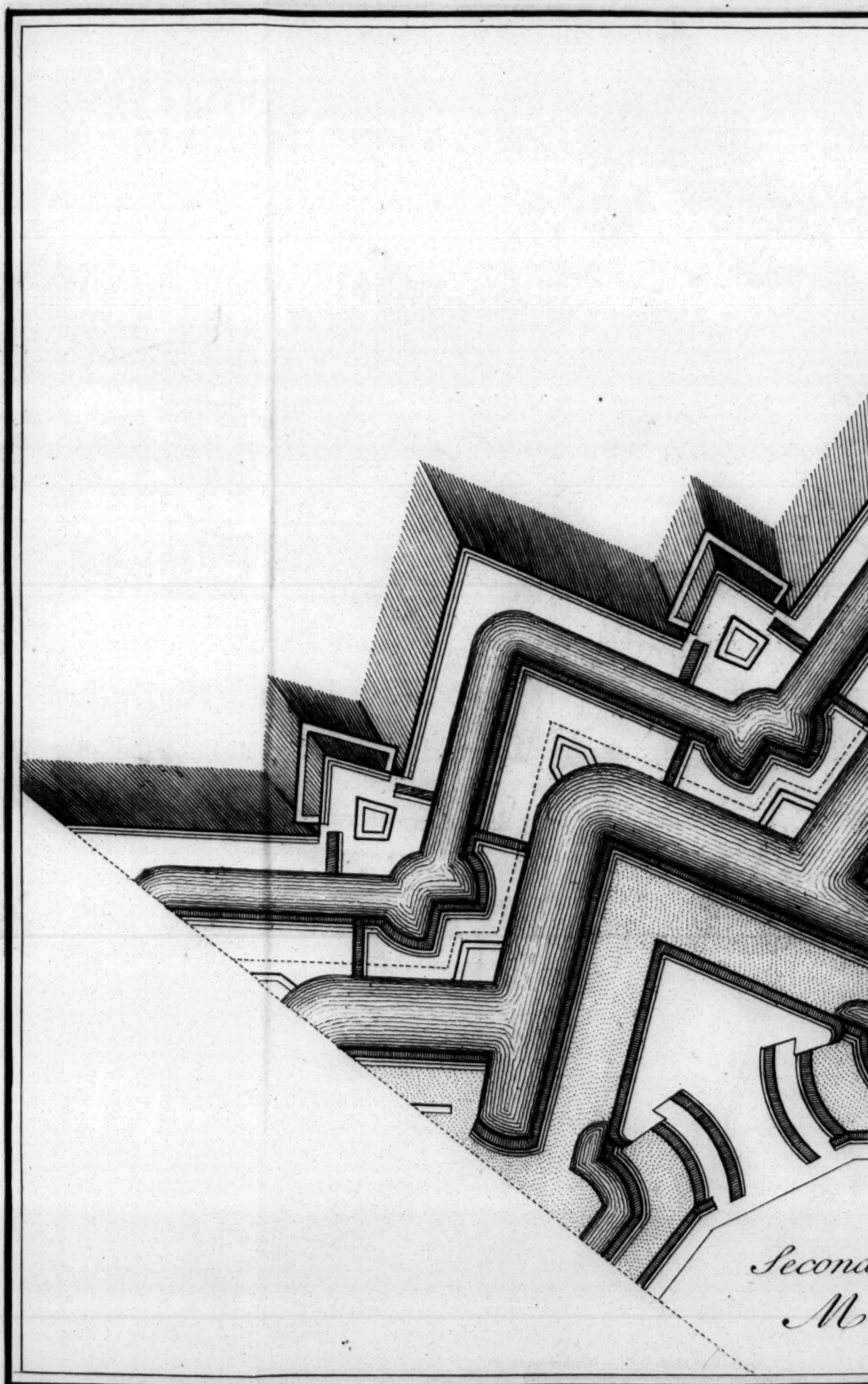


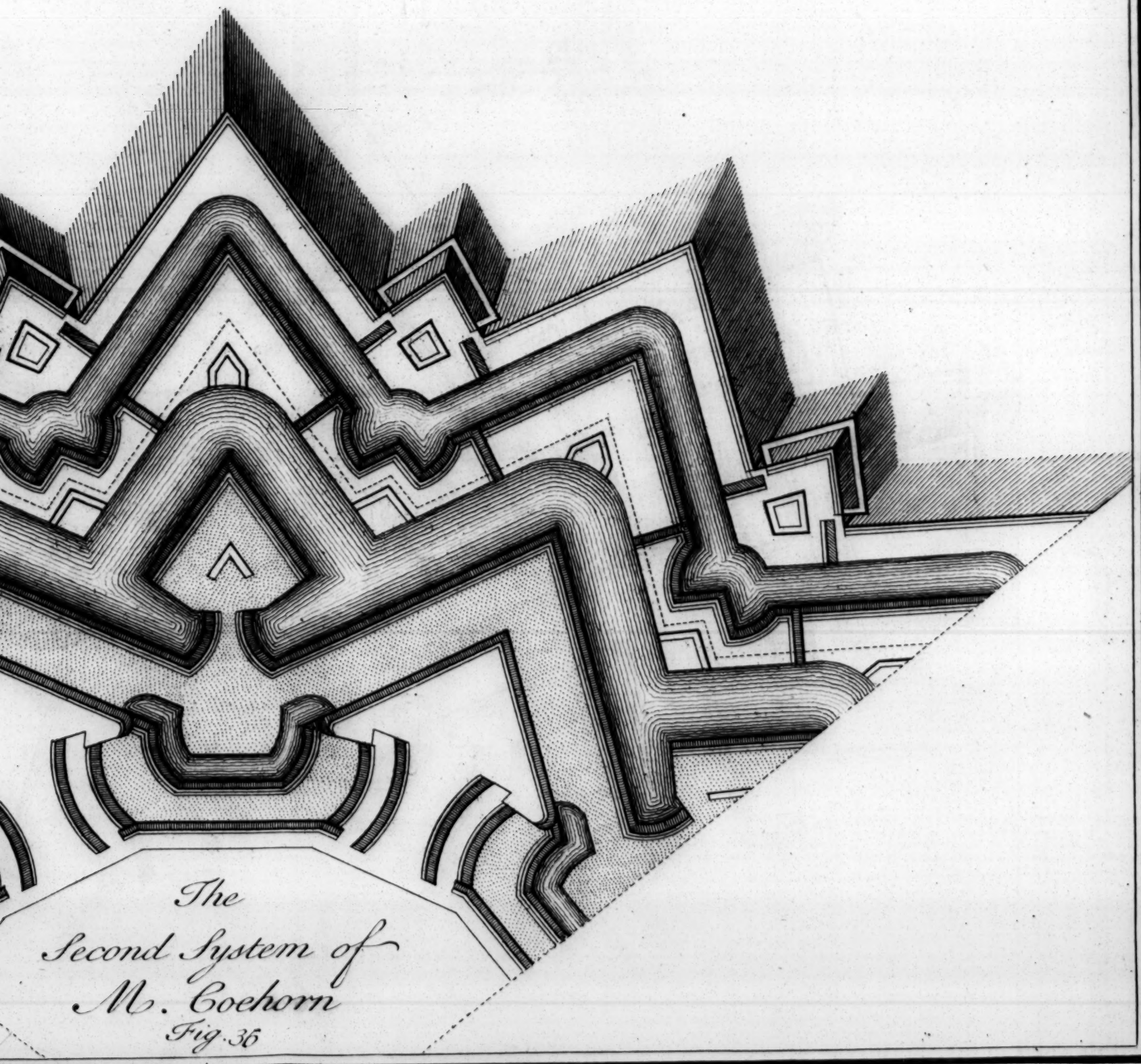
he first System
of
Mr. Cochorn

Fig. 32

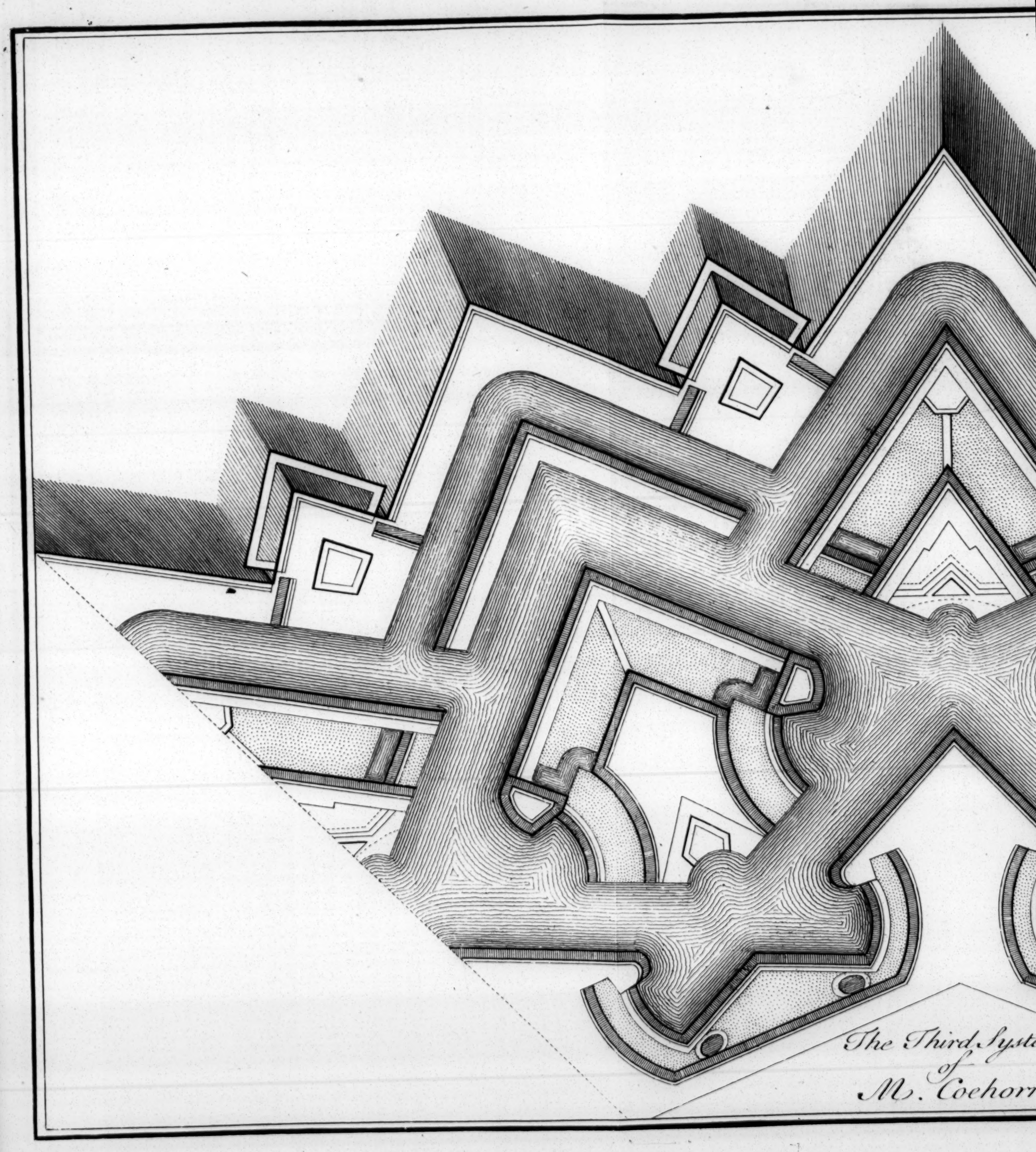
The Turning Pallisades
for the Covert Way

Fig. 34

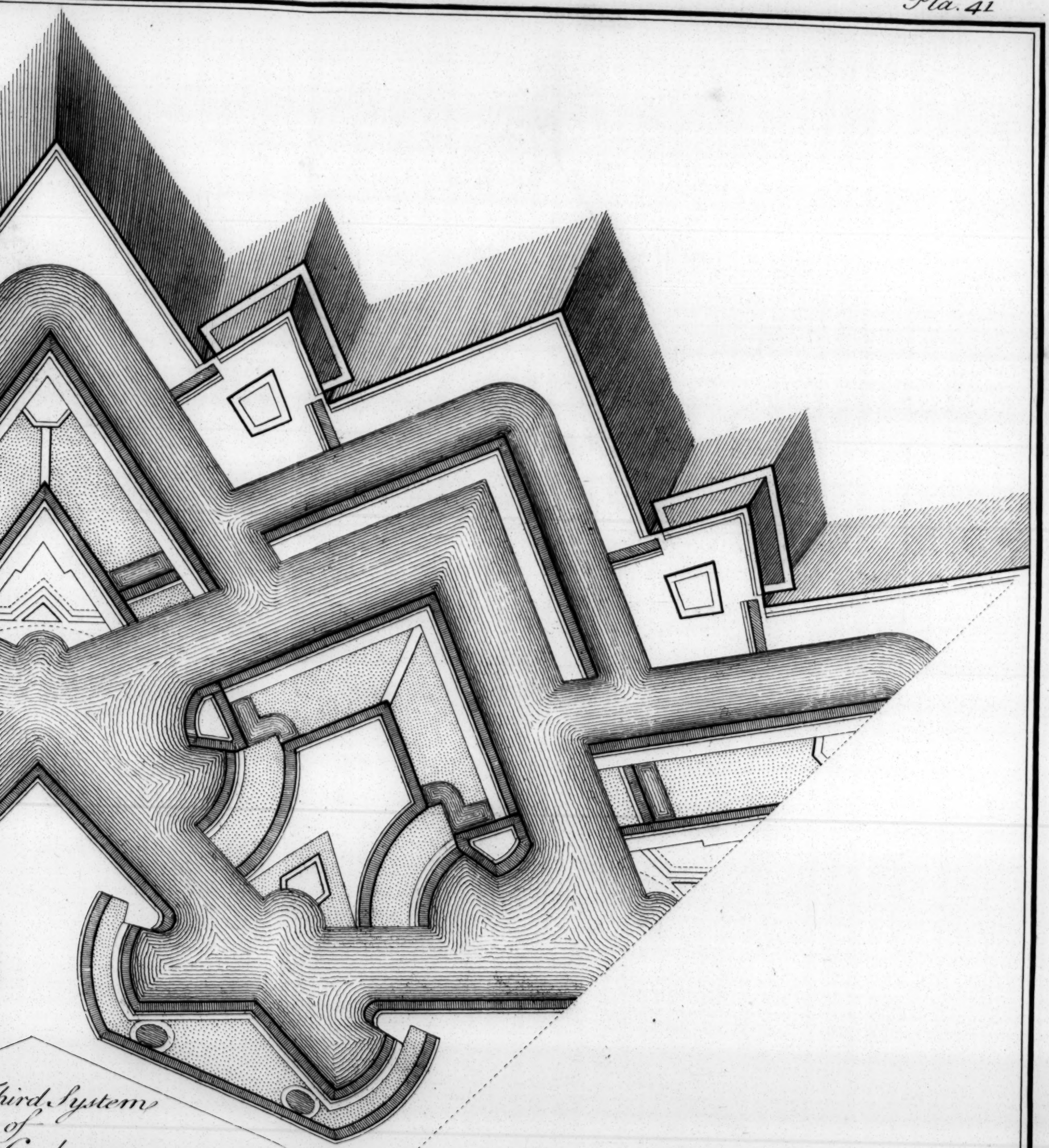




The
Second System of
M. Coehorn
Fig. 36



The Third Syste
of
M. Coehorn



hird System
of
Coehorn

utmoſt difficulty and exceſſive expence that the beſiegers can bring before them all things neceſſary for a ſiege; moreover, if their foundations are rocky, they are in no danger of the enemy's mines; and the mountain being very ſteep on all ſides, it is impoſſible for the beſiegers to ſee and batter them, but at a very great diſtance; whereas thoſe in the fortreſs can ſee and command on all ſides; ſuch is the ſituation of *Montmidi* in the Dutchy of *Luxemburgh.*

What can be objected to places built upon high mountains is, that they are for the moſt part of a very ſmall extent, conſequently all the parts of the fortifications are alſo ſmall; hence it follows, that they cannot make a very vigorous defence; beſides, there are but few of theſe places that will admit of being fortified regularly, or according to the true maxims of the art. Water is not to be had in plenty, unleſs a very good well be made in the place that cannot be dried up. The materials for the ſtructure of the works of a fortreſs thus ſituated, and the artillery and ſtores, are brought thither but with great difficulty. That ſuch places are not to be ſuccoured eaſily, and when their ſituation is very high they cannot be eaſily defended, becauſe their cannon firing downwards againſt the beſiegers, their ſhot do not act with equal force and violence as thoſe that are fired upwards; and unleſs there are good ſouterrains in theſe ſmall fortreſſes, the garriſon, ſtores, *&c.* are quite expoſed to the terrible effects of their enemy's bombs. It is very rare but that places ſituated on a mountain are commanded by other neighbouring eminences.

2. The moſt advantageous ſituation for places in a flat country is, when they are erected upon a riſing ground, without being commanded in the leaſt, as *Philippe-Ville*

in the Earldom of *Hainault*. There can be no ſcarcity of water, becauſe they can have as many wells dug as are neceſſary. The earth is generally of a good quality for raiſing ſtrong ramparts and parapets, but theſe fortifications would be judged imperfect, unleſs they were carefully countermined.

The fire of the cannon from the ramparts are razant, and conſequently can act with much greater violence than when it is plunged from an extraordinary height downwards; but then ſuch places are faulty, becauſe the good quality of the earth ſerves the beſiegers in making their lines of circumvallation to retrench their camp; the trenches alſo are carried on with great ſucceſs and ſpeed, their batteries are ſoon ready, and their miners work with all deſirable eaſe and advantage; the great plenty of forage and proviſions that the ſoil produces, affords a certain ſubſiſtence during the ſtay of the army in thoſe quarters.

3. Places ſituated in marſhy grounds are free from any eminence that commands them, and the beſiegers cannot approach but with great risk of periſhing in ſeveral parts. Theſe fortifications cannot be undermined, at leaſt without infinite difficulties; for what a laborious task muſt it be to carry on a ſap of any depth in grounds conſtantly covered with water iſſuing from numberleſs ſprings, all which it is impoſſible to ſtop. The fortifications for theſe places may be raiſed with little charge, becauſe oftentimes they are fortified by nature on every ſide, excepting one or two, which are the only parts where the beſiegers can make their attacks, therefore they do not require a numerous garriſon.

But fortreſſes ſituated in marſhes have ſeveral conſiderable diſadvantages. Their works can only be raiſed of earth,

earth, which earth being taken from the marſh, is not of due conſiſtence for ramparts and parapets; and if it was propoſed to line the works, it cannot be done but with exceſſive coſt, for three reaſons; the firſt is, becauſe the foundation muſt be laid upon piles, and timber being ſcarce in marſhy ſoils, it muſt be brought perhaps from a great diſtance; ſecondly, the earth not being of a fit quality for making of bricks, theſe materials, as well as the ſtones, muſt likewiſe be brought from other places; thirdly, the fortifications of a place in a marſhy ſituation, lined or not, coſt more to keep in repair than any other; and the walls of the lining, when battered by the enemy's cannon, cannot withſtand their violence ſo long as in other places, becauſe the earth does not bind ſo well with it, therefore the foſsè is ſoon filled with the ruins of the ramparts.

The vapours and fogs that are exhaled from the ſtanding-waters of the marſhes corrupt the air, and occaſion ſeveral epidemical diſeaſes, oftentimes mortal to the greateſt part of the garriſon; add to theſe, that the marſhes, which for the greateſt part of the year are the chief ſtrength of the fortreſſes, are oftentimes the cauſe of their being taken in the cold ſeaſon, the froſt which then comes on affording to the beſiegers the means of ſurpriſing them.

4. There are places quite ſurrounded with water, theſe need but few works to fortify them. If it is by the ſea, or a large river, the ſhipping and boats of an enemy may eaſily be ſet on fire by the beſieged, if they ſhould venture to come too near; though, at a great diſtance, the force of gun-ſhots upon the ſurface of the water is diminiſhed. Theſe ſituations are preferable to marſhy ones, for they are more healthy as it is a running water, and not ſo liable to be frozen, therefore the fortreſs cannot ſo eaſily be ſurprized.

The objections made againſt places that are quite ſurrounded with water are, that the enemy can intercept all manner of ſuccour; and if they are blocked up by a ſufficient fleet, either of ſmall or large ſhips, they muſt unavoidably fall by famine, without any other methods practiſed againſt them; but ſuch places having a brave governor, with ſufficient quantities of neceſſary ſtores and ammunition, the enemy will require much more time to ſucceed in their deſigns, than is requiſite in a regular ſiege.

5. Laſtly, there are other places of the utmoſt importance upon the borders of great rivers; theſe have the conveniency, that all materials neceſſary for their conſtruction, as well as all manner of artillery, ſtores, *&c.* are conveyed by water-carriage.

Thionville, which ſtands in a vaſt plain upon the *Moſelle*, and many others along the *Rhine*, have this advantage, and with moderate expences could be rendered ſome of the ſtrongeſt fortreſſes in *Europe*, for places thus ſituated can be regularly fortified, or at leaſt in part, and the ſide towards the water can coſt but very little, a ſtone or brick wall with redans being ſufficient fortifications for it. Succours are eaſily introduced into theſe places. The adjacent country can be laid under water. The earth is generally of a good quality for the conſtruction and repairs of the works.

The enemy muſt have a large army to beſiege this ſort of fortreſſes, becauſe the quarters are not only ſeparated, but alſo are at a great diſtance one from the other.

The following defects are attributed to places upon the borders of great rivers.

That the advantages of their ſituation is as favourable for the enemy as for themſelves; all the artillery, ſtores, *&c.*

neceſſary

neceſſary for a ſiege, can be brought by water with great eaſe, and with little expence, and more eſpecially ſo if the current of the flood is not againſt them. Beſides, the earth being good, they may fortify their camp with ſtrong lines not to be forced.

The knowledge of the good and bad quality of earth is much better learnt by experience than by any deſcription laid down in writing, and it is not intended to be treated of in theſe ſheets.

To trace a plan upon the ground.

IT will be no difficult task, for any one who is become acquainted with practical geometry and the elements of fortification, to trace the plan of a fortreſs upon the ground; for inſtead of the ruler and compaſſes, thoſe inſtruments muſt be made uſe of which are required for ſurveying, *viz.* the *theodolite*, *circumferentor*, *ſemicircle*, *plain-table* or *compaſs*, *level*, *chains*, *ropes*, *pickets* of different ſizes, &c. Thus to trace any ſide of a polygon for a place ſuppoſed to be already filled with buildings; having taken upon paper an exact plan thereof, you may eaſily find the points where to fix the angles of the interior and exterior polygons, which fortify according to the principles of this ſcience; as yet we ſuppoſe them regular, becauſe we defer ſpeaking of irregular fortifications till the following chapter.

The plan from which you trace the lines upon the ground muſt be deſcribed upon a great ſcale, and only with the occult and magiſtral lines; theſe lines muſt have their lengths exactly marked out, as well as their ſaillant and re-entering angles. Thus, with a ſemicircle, you may trace upon the ground ſimilar angles to thoſe in the plan which

is fixed upon a plain table. The angles are marked by pickets, and the lines, are carefully meaſured with the chain, giving to each their exact length. The diſtance from picket to picket for the magiſtral line is to be marked out by a little furrow, with a pickax in a right line, and you will have the ſame figure upon the ground as in the plan.

Repeat this operation for all the remaining ſides of the place; afterwards, with a level, find out the differences of the aſcents and deſcents, which mark down upon pickets, and fix the horizontal line by raiſing thoſe which are too low, and lowering the higher ones, ſuppoſing their differences not ſo conſiderable as to render this impracticable. If the center of the place is not naturally higher than any part of the circumference, it muſt be raiſed five or ſix feet, or other methods uſed to drain off the waters.

As to the foundation of the curtins, baſtions, &c. with every thing elſe that relates to the real ſtructure of fortifications, we never did deſign to give them places in this treatiſe; moreover, their knowledge is no ways different from that which is requiſite for executing any deſign of civil architecture.

CHAPTER

CHAPTER V.

OF IRREGULAR FORTIFICATION.

ALL that has been hitherto ſaid was in relation to regular fortification, which cannot be made uſe of but in *new places*, where the ground may be equally extended; or in *old* ones, where they have room enough about them, and may otherwiſe be made regular, without an exceſſive charge. But as it is ſeldom that new towns are to be built, and when they are, it is as ſeldom that ſuch a favourable ſituation may be had for them as would give one a full ſcope and liberty of acting; and as, on the other hand, almoſt all that are to be fortified are old ones, whoſe circumference is often ſo irregular as would require a very great charge and expence to rectify; it will be neceſſary to know how to proceed on theſe occaſions, which is the buſineſs of irregular fortification.

A place may be ſaid to be irregular, either firſt, only in its figure, when the angles are not equally diſtant from the center, yet are all of them capable of a good baſtion, the lines being of a proper length; or ſecondly, in its figure and angles, ſome of which may be too acute, and others re-entering; or thirdly, in its figure and ſides, theſe being ſometimes too long, and ſometimes too ſhort; or laſtly, in its figure, angles, and ſides together. It will be ſufficient to give rules for correcting the three former, and then the method for the latter will be known of courſe.

It is abſolutely neceſſary to reduce irregular places to regularity, as much as may be, becauſe by that means their

ſtrength

ſtrength becomes equal every where; but if it cannot at all be done, the principal rules, at leaſt, of regular fortification muſt be obſerved; that is, to ſee that all the parts be well flanked; that the angles of the baſtions be not under 60 degrees; that the defence be as much as poſſible within musket-ſhot, or at leaſt that a defect in this be remedied by ſome out-work; and laſtly, that the ſtrength of the place be equally diſtributed all around, as much as the irregularity will allow of. But here care is to be taken to avoid a fault that has been made by ſome, who becauſe one ſide happens to be weak, diminiſh the ſtrength of the other, that they might all be in the ſame degree of ſtrength; this is manifeſtly abſurd, to weaken the whole for the ſake of a part, which might otherwiſe have been made good by ſome out-work.

To make an irregular place regular, when it may be done.

Fig. 1. LET the irregular pentagon A B C D E be to be made regular, whoſe greateſt ſide C D is 200 fathoms; deſcribe a circle whoſe circumference ſhall go through the points of the three moſt diſtant angles A C and D; this is done by joining them with the right lines A C, C D, and biſſecting them with perpendiculars which cut one another in M, which being taken for a center, deſcribe a circle whoſe circumference paſſes through A, and it will alſo paſs through C and D; then make a ſcale on the longeſt ſide, C D, of the given figure; divide it into as many parts as it contains fathoms, that is into 200, and take 180 with your compaſſes and put it upon the circumference as many times as it will go. If the circumference contains it a certain number of times exactly, without

out any remainder, for inſtance ſix or ſeven times, you'll have a regular polygon of ſix or ſeven ſides, which you'll fortify by the method of M. *de Vauban*; but if, after having laid the 180 fathoms, as often as could be upon the circumference, there ſhould remain ſomething over; then, in the ſtead of 180, you muſt take 185, and begin again. If there ſhould ſtill be any thing remaining, you muſt again increaſe your number until it occupies the whole circumference. It is in this manner that we have made the regular pentagon AILOP, whoſe ſides are 190 fathoms each.

Note, That if we had worked by diminiſhing the number of 180 fathoms, inſtead of increaſing them, we ſhould then, inſtead of the pentagon, have got the hexagon ARSTVX, whoſe ſides would have been 160 fathoms; but as by this method there is more to be taken off from the 180 fathoms (the exterior ſide according to M. *de Vauban*) than is required to be added, in order to obtain the ſide of the pentagon, we give the preference to this latter way; which always ought to be done on like occaſions, to vary as little as may be from the rule.

The Chevalier St. *Julien* makes uſe of another method, which we will explain in this place. He diſtinguiſhes two ſorts of irregular places, ſome of which may eaſily be circumſcribed by a circle, whilſt others cannot on account of their length.

As for the former, he deſcribes on their figure ABCDEFG, a ſquare HILM, whereby he takes in nearly as much ground as is loſt; and drawing the diagonals HL and MI, and making the point of interſection a center, he deſcribes a circle about the ſquare, and finiſhes all as above. Fig. 2.

As to oblong places, ſuch as A B C D E F G H I, he draws upon the face of their figure a paralellogram
Fig. 3. L M N O, taking care ſtill to gain about as much ſpace on the one hand as is loſt on the other; then on the long ſide N L, he raiſes an iſoſceles triangle L 8 N at diſcretion, from the top of which 8 he deſcribes the arch N X V L, and works in the ſame manner on the other long ſide M O, which gives him the other arch O R M; that done he makes, on the ſhort ſide L M, the iſoſceles triangle L 7 M, of a diſcretional height; and likewiſe making ſuch another on the other ſide N O, from the tops of the triangles he deſcribes the arches L T M, N P O, which meeting with the former make an oval, whereon he finiſhes the reſt as aforeſaid.

This method may be made uſe of in places that are nearly ſquares; but as for oblongs, we ſhall preſently ſhew a method of working them, which we take to be much better than his.

To find the exterior ſides of a place, the interior only being given.

IN the foregoing articles we have taken it for granted, that the ſides of the irregular pentagon, which was to be made regular, were the exterior ſides, within which the baſtions might be built without diminiſhing the area or magnitude of the place; But as theſe exterior ſides cannot always be had, and as the plans of old towns that are to be fortified ſhew their circumference upon which the baſtions are to be placed externally for fear of incroaching on the ground within, it will not be eaſy in theſe caſes to make uſe of the method of M. *de Vauban*, who

who always begins by the exterior ſide: So that we have given a table, by the means of which any interior ſide being given, its correſponding exterior ſide may eaſily be found. I know that on theſe occaſions there are ſome who fortify within, by ſetting off the demigorges, the flancs and their angles, to which they give the dimenſions given them by M. *de Vauban*; but this method is ſubject to faults and errors, that we are pretty ſure the following is no ways liable to, as will appear by applying both to one and the ſame figure.

A Table to find out the exterior sides of a place, when its interior sides are given.

The Square			The Pentagon			The Hexagon		
Interior side	Distance of the polyg.	Exterior side	Interior side	Distance of the polyg.	Exterior side	Interior side	Distance of the polyg.	Exterior side
fathoms	fathoms	fathoms	fathoms	fathoms	fathoms	fathoms	fathoms	fathoms
129	38	200	140	40	200	145	48	200
124	36	192	135	39	193	140	46	193
119	35	184	130	37	186	135	45	186
114	33	176	125	36	179	130	43	179
109	32	168	120	35	172	125	41	173
104	31	160	115	34	164	120	40	165
			110	33	157	115	38	158
Angle of he polyg	90 degrees		Angle of the polyg	108		Angle of the polyg	120	

The Heptagon			The Octogon			The Enneagon		
Interior side	Distance of the polyg.	Exterior side	Interior side	Distance of the polyg.	Exterior side	Interior side	Distance of the polyg.	Exterior side
158	46	200	161	51	200	167	50	200
153	45	194	156	49	194	162	48	194
148	43	188	151	47	188	157	47	188
143	42	181	146	46	182	152	45	182
138	40	175	141	45	175	147	44	176
133	39	169	136	43	169	142	42	170
128	37	162	131	42	163	137	41	164
123	35	156	126	41	157	132	39	158
Angle of the polyg	129		Angle of the polyg	135		Angle of the polyg	140	

The Decagon			The Endecagon			The Dodecagon		
Interior side	Distance of the polyg.	Exterior side	Interior side	Distance of the polyg.	Exterior side	Interior side	Distance of the polyg.	Exterior side
170	49	200	170	50	200	176	47	200
165	47	194	165	48	194	171	45	195
160	45	188	160	47	188	166	43	189
155	44	182	155	45	182	161	42	183
150	43	176	150	44	176	156	41	177
145	41	170	145	43	170	151	40	172
140	40	164	140	41	164	146	38	166
135	38	158	135	40	158	141	37	160
Angle of the polyg	144		Angle of the polyg	148		Angle of the polyg	150	

The

The firſt column of this table exhibits the different interior ſides that are given; the ſecond, which is called the diſtance of the polygons, ſhews the length of a perpendicular drawn from the middle of the interior ſide to the middle of the exterior; laſtly, the third gives the exterior ſides correſponding with the interior ones.

I have exhibited in this table only the interior ſides that are proportional to the exterior ones, that are in length between 200 and 160 fathoms, becauſe ſuch only are reputed regular according to M. *de Vauban*'s method; but if it were required to find an exterior ſide correſponding with an interior one, greater or leſs than any of thoſe in the table, the way to do it would be, only with the help of the *rule of three*, in the following manner:

Suppoſe an exterior ſide were wanted proportional to an interior one of 166 fathoms belonging to an octogon. Look out the greateſt interior ſide of an octogon in the table, *viz.* 161, with its correſponding exterior 200; then ſay, if 161 give me 200, what will 166 give? and the anſwer will be 206 the exterior ſide required. The perpendicular may be had in the ſame manner, ſaying, if 161 give 51, what will 166 give? and there will come out for an anſwer about 53.

The interior ſides laid down in the table exceed one another by five fathoms, and conſequently their correſponding perpendiculars and exteriors only are ſhewn; but if a perpendicular and an exterior ſide were required anſwerable to an interior one of an octogon, ſuppoſe whoſe ſide ſhall be 158 fathoms long, *i. e.* between 161 and 156, you muſt here likewiſe make uſe of the *rule of three*, and ſay, if 161 give 200, what will 158, *&c.* even, the making uſe of this rule might be altogether omitted; for ſince the interior ſide 158 is between 161 and 156, the

exterior

exterior ſides of which are 200 and 194, a mean number might be taken betwixt theſe two laſt nearer 194 than 200, becauſe 158 comes nearer to 156 than to 161, and that number might be 196; in the ſame manner as the perpendicular of 156 is 49, and that of 161 is 51, the perpendicular might be taken of 158, 49 fathoms, and four or five feet more.

What we have here ſaid might be practiſed in order to find out an exterior ſide anſwerable to an interior one, whether it be greater or leſs than thoſe ſpecified in the table. For ſuppoſe, for inſtance, that an exterior ſide was wanting anſwerable to the interior ſide 171 of an octogon, we muſt recur to the table to find out how the exterior ſides increaſe in proportion as the interior ones increaſe by 5; and having then diſcovered that theſe ſides are augmented by 6 fathoms, the exterior ſide of 171 muſt have 12 fathoms more than that of 161 has, which is the largeſt in the table, becauſe 171 is more than 161 by 10, and that as the interior ſides augment by 5, the exterior increaſe by 6, the which gives 12 when one interior is greater than another by 10 fathoms.

'Tis eaſy to ſee, without any farther explanation, what is to be done in order to find out the exterior ſides, anſwerable to the interior ones that are leſs than thoſe in the table, and how to find out their perpendiculars. 'Tis true indeed, that according to this method the exterior ſides and perpendiculars will not be found ſo exact as if the *rule of three* was made uſe of; but in fortification a geometrical exactneſs need not be obſerved, and, provided every ſide be but well defended and ſecured, one, two, or three fathoms, more or leſs, will make no difference at all. Wherefore we have even neglected the fractions which we found in calculating the table, which we would not have

any

any one ſcrupulouſly adhere to, but add or diminiſh ſomewhat whenever the defence may thereby be the better ſecured.

But to come to the practice:

Suppoſe we have a place to fortify whoſe interior ſides are A B, B C, C D, D E, E F, F G, G A; we begin by the largeſt ſide A B, which is 158 fathoms, we examine the angles A and B which are on each ſide, and find that the greateſt B is 150 degrees, and conſequently belongs to the dodecagon, as may be ſeen in the preceding table, where we have marked the angles of the polygons. We take then, in this table, the height of the perpendicular which anſwers to the interior ſide 158 of the dodecagon; and as we only find the interior ſides 156 and 161, between which is 158, we take the perpendiculars of theſe two ſides, which are 40 and 41, and add ſomething to the ſmall one 40, ſo that the perpendicular which we have by this increaſe is nigher 40 than 41, as 158 is nearer 156 than 161. We allow then about two feet, which will give us 40 fathoms and two feet for the perpendicular. We raiſe this perpendicular about the middle of the interior ſide A B, and at its extremity draw an indefinite line parallel to its interior ſide. This done, we come to the ſide B C, which is 153, and having found that the angle which it makes in C, with the ſide C D, is 29 degrees, the angle of the heptagon, we look into the table for the perpendicular anſwerable to the interior ſide 153 of the heptagon; this perpendicular is 45 fathoms, ſo that we raiſe it at the middle of the ſide B C, or without doing this, draw an indefinite line parallel to its interior ſide, at the diſtance of 45 fathoms for its exterior ſide. We do the ſame thing on the other ſides, and find at laſt that all thoſe indefinite lines determine each other by their interſection, and give me the outward ſides required. Fig. 4.

You

You muſt take care to begin by the longeſt ſide, and chooſe the greateſt of the two angles which it makes with the other two ſides, in order to determine its perpendicular, as we have done; then come to the ſide which makes the angle you have pitch'd upon, and, in order to determine its perpendicular, always take the angle which it makes with the following ſide, and not that which you had taken for the preceding one; which muſt be continued ſo to the very end, that each angle may determine its proper perpendicular.

The work thus done, you will not find that the exterior ſides are of the ſame length as the table ſhews them, in proportion with the interior ſides, which would always be was the figure regular; becauſe the ſides and angles being then equal, the perpendiculars would be equal too; whereas here, as the perpendiculars are unequal by reaſon of the inequality of the ſides and angles, it neceſſarily happens that the exterior ſides of the ſhorteſt perpendiculars encroach upon thoſe of the longer; but in this very thing ariſes a conſiderable advantage from this method, becauſe, as the exterior ſides of the little perpendiculars anticipate upon thoſe of the greater, at the ſame time that they diminiſh them they increaſe themſelves, which is the cauſe that the exterior ſides become pretty equal, and that the figure comes neareſt to a regular one; nay, it even happens that the interior ſides, which are naturally irregular, as thoſe of 90, 80, or 70 fathoms, do by this means become regular, provided they be contiguous to great ſides, becauſe, as their perpendicular is very ſmall, their exterior ſides anticipate greatly upon the others; and for the ſame reaſon interior ſides that are greater than they ſhould be, as are thoſe of 175, 180, *&c.* may be rectified, provided they be contiguous to ſmall ſides, becauſe their exterior ſides will be much diminiſhed by the

anticipation

anticipation of the exteriors of the ſhorter. We ſhall mention the other advantages ariſing from this method, above thoſe which ſome authors make uſe of, when we have ſhewn how and in what manner the exterior ſides which we have now found out are to be fortified.

To fortify an irregular place, whoſe ſides and angles are regular.

SUPPOSE we had the ſame irregular place to fortify ABCDEFG, all whoſe ſides and angles are regular, and the leaſt of the angles 108 degrees, which is the angle of the pentagon. We muſt find out the exterior ſides, as we did in the foregoing article; and the figure having ſeven ſides, it muſt be fortified as a regular heptagon, *i. e.* raiſe a perpendicular in the middle of the exterior ſide inwardly, and give it a ſixth part of the exterior ſide; then draw lines of defence at the perpendicular's extremity; take the faces equal to two ſevenths of the exterior ſide, and determine the flancs and curtins as we have ſaid, according to M. *de Vauban*'s firſt method. Fig. 4.

And ſhould the flanked angle of any of the baſtions become too acute, which here happens to the baſtion G, becauſe the angle of the figure in this place is but 108 degrees, we ſhould then allow but the ſeventh or eighth part to the perpendiculars of the outward ſides which form that angle, as we have done, although we were under no abſolute neceſſity of doing it.

By this means the figure would be as well fortified as its irregularity would admit of, and the very extent of the place would be increaſed; the flancs, faces, and curtins would have their proper proportion, and the baſtions would always be large and well-defended, becauſe thoſe whoſe

capital diminiſhes, which is the caſe of obtuſe angles, have alſo their gorges much greater than thoſe whoſe capital does not diminiſh. Indeed there are baſtions whoſe flanked angle is very obtuſe; but it is a defect that cannot be avoided in irregular fortification, no more than it can in great polygons, unleſs there are double flancs, the inconveniencies of which are much greater, as has been obſerved by us elſewhere.

Fig. 5. Some there are who fortify theſe places from within, without looking for the exterior ſide, as it is here, they always give the demigorges a fifth part of the interior ſide. Then if the interior ſide be from 60 to 80 fathoms, they allow each flanc 15, which, with the curtin, always makes an angle of 100 degrees; after that, they draw lines of defence razant, which being interſected by the lines of the other ſides, determine the fronts. If the interior ſide is from 80 to 100 fathoms, the flancs are increaſed by one fathom, as the ſide increaſes by 10; from 100 fathoms to 140, they augment the flancs by one fathom, as the interior ſide increaſes by 5; *i. e.* when the interior is 105 the flancs are 19, and when 110 the flancs have 20, and ſo on. Laſtly, from 149 to 160 the flancs increaſe by half a fathom, as the interior ſides augment by 5, the which will more eaſily be underſtood by this table, where 140 and 145 have the ſame length for the flanc.

Interior ſide	60	80	90	100	105	110	115	120	125	130	135	140	145	150	155	160
Flanc	15	16	17	18	19	20	21	22	23	24	25	25½	25½	26	26½	27

According to this method we have fortified the polygon, figure 5, whoſe angles and interior ſides are the ſame as thoſe of the fourth figure, the better to ſee how advantageous

geous our method is, and how defective this is. Firſt, the interior ſides, each of them remain in their original length, nor is the irregularity of the place in the leaſt diminiſhed. Secondly, the faces have ſeldom their exact proportions with the flancs, becauſe the angles are irregular, which cauſes theſe to diminiſh whilſt the others increaſe, ſo that often the leaſt flancs have the greateſt faces to defend, as may be ſeen in the baſtions G, A. Thirdly, the faces of the ſame front are always unequal, becauſe as the angles are unequal, it happens that the lines of defence belonging to the other fronts increaſe one face, whilſt they diminiſh the other, which is evident in the baſtions A, B, F, G. Laſtly, the baſtions F, B, which are upon very obtuſe angles, have their capitals leſs than the others, although their gorges do not increaſe proportionably, which renders them leſs capable of a good and proper defence.

Again, according to this method it happens, that if a little ſide, for inſtance, of 100 fathoms, ſhould be found between two great ones of 160 fathoms, or thereabouts, the faces of the little ſide by this means become exceeding large, and the flancs extremely ſmall, as may be ſeen in the plate, where the black ſtrokes mark the fortification of a place, according to the ſcheme of theſe authors, and the dotted lines mark it according to ours; by which means the leaſt ſide is corrected, and every part, in reſpect of its front, has its juſt and exact proportion; which, we think, ought never to be neglected, that the enemy, who commonly leads on his attack on a front, *i. e.* from the point of one baſtion to that of another, may not find any one ſide of that front weaker than the other is. Fig. 6.

The defects we have diſcovered in this ſcheme, and the advantages which we find in ours, is a ſufficient reaſon to prefer this to the other; however in this, as in any thing

elſe, we ſhall wait the deciſion of the ingenious, and ſhall ever eſteem it an honour to abide by their opinion.

To fortify an oval.

AN oval, properly called an *ellipſis*, may be made uſe of for fortifying of towns and places, whoſe ſituation extends more in length than in breadth.

Fig. 7. An oval is made in the following manner. Draw the right line A D to any length; divide it into three equal parts A B, B C, C D; making C a center with the diſtance C D, deſcribe the circle D M E B F N, then lay the length of the radius in the circumference from D to M, and from D to N. From B a center, with the diſtance B A, deſcribe the circle A L E C F I, and lay alſo in the circumference the length of the radius from A to L, and from A to I, theſe two circles will cut one another in the points F, E. Set one foot of the compaſs upon F, the other upon M, and draw the arch M G L, which ſhall end in L; ſet likewiſe one foot of the compaſs upon the point E, the other upon the point I, and draw the arch I H N, which ſhall end in N; and this will finiſh the oval H N D M G L A I.

If you draw a right line through the points E, F, until it meet with the circumference of the oval both ways, this line will cut the firſt, A D, perpendicularly, and divide it into two equal parts in the point O, which is called the center of the oval. The line A D is called the *great diameter*, and the line G H the *little diameter*, which is a little more than three quarters of the great diameter.

Now if you divide the circumference of the oval, for inſtance, into ſix equal parts, and after having drawn right lines from the points of diviſion, you fortify theſe lines inwardly

wardly as before, you will have an hexagon, which will be almoſt a regular one. Fig. 8.

For example. Suppoſe the exterior ſide were 180 fathoms, make this your ſcale, and you'll find that the great diameter DC is 410 fathoms; that the part of it, AB, which is within the place, and which we ſhall name the *interior length*, is 250 fathoms; that the parts BC, DA, which are without, are each of them 80 fathoms, and, added together, 160, which we ſhall call the *addition of the interior length*. You'll alſo find, that that part, FE, of the leſſer diameter, which is contained within the center of the demigorges of one baſtion, and the center of the demigorges of the oppoſite one, is 210 fathoms, which we name the *interior breadth*; that the parts GE, FH, (which may not improperly be ſaid to be without, as they ſerve for capitals) are jointly 100 fathoms, which we call the *addition to the interior breadth*; and that the leſſer diameter is 310 fathoms.

Hence it is that we have made a table, by the help of which the interior length of a place being given, it will be eaſy to find, not only what is to be added to that length, to make up the greater diameter on which the oval is to be made, but alſo, what ſort of polygon is to be inſcribed in the oval, and what length its exterior ſide is to be of: And this, we take it, will be of great uſe in practice, either for new places, whoſe interior lengths are determined, or for old ones, that are to be newly fortified, whoſe plans ſhew us a fixed length which cannot eaſily be diminiſhed without diminiſhing the body of the place.

A table

A table for finding the great diameter of an oval, the polygon that may be inſcribed in it, and the length of its exterior ſide, the interior length being given.

For the Pentagon.

Interior length	Addition to the length	Greater diameter	Exterior ſide	Interior breadth	Addition to the breadth	Leſſer diameter
fathom						
208	158	366	190	174	103	277
202½	154	356½	185	169½	100	269½
197	150	347	180	165	97	262
191½	146	337½	175	160½	94½	255
186	142	328	170	156	92	248
180½	138½	318	165	151	89½	240½
175	133½	308½	160	146½	86½	233

For the Hexagon.

Interior length	Addition to the length	Greater diameter	Exterior ſide	Interior breadth	Addition to the breadth	Leſſer diameter
fathoms						
264	169	433	190	221½	105½	327
257	164½	421½	185	216	102½	318½
250	160	410	180	210	100	310
243	155½	398½	175	204	97	301
236	151	387	170	198	94½	292½
229	147	376	165	192½	91½	284
222	142½	364½	160	187	88½	275½

For the Heptagon.

Interior length	Addition to the length	Greater diameter	Exterior ſide	Interior breadth	Addition to the breadth	Leſſer diameter
fathoms						
340	156	496	190	274	101	375
331	152	483	185	267	98	365
322	148	470	180	260	95	355
313	144	457	175	253	92½	345½
304	140	444	170	245½	90	335½
295	136	431	165	238	88	326
286	132	418	160	231	85	316

For

For the Octogon.

Interior length	Addition to the length	Greater diameter	Exterior side	Interior breadth	Addition to the breadth	Leſſer diameter
fathoms						
454	105	559	190	319	103½	422½
442	103	545	185	310½	100½	411
430	100	530	180	302	98	400
418	97	515	175	293½	96	389½
406	94½	500½	170	285	93½	378½
394	92	486	165	276	91	367
382	89	471	160	268	88	356

For the Enneagon.

Interior length	Addition to the length	Greater diameter	Exterior side	Interior breadth	Addition to the breadth	Leſſer diameter
fathoms						
502½	126½	629	190	380	95½	475½
489	123½	612½	185	370	93	463
476	120	596	180	360	90	450
463	116	579	175	350	87½	437½
449½	113½	563	170	340	85½	425½
436	111	547	165	330	83½	413½
423	108	531	160	320	81½	401½

For the Decagon.

Interior length	Addition to the length	Greater diameter	Exterior side	Interior breadth	Addition to the breadth	Leſſer diameter
fathoms						
554	148	702	190	432	99	531
539½	144	683½	185	420½	96½	517
525	140	665	180	409	94	503
510½	136	646½	175	397½	91½	489
496	132	628	170	386	89	475
481	128	609½	165	375	86	461
466½	125	591½	160	363½	84	447½

For

For the Undecagon.

Interior length	Addition to the length	Greater diameter	Exterior ſide	Interior breadth	Addition to the breadth	Leſſer diameter
fathoms						
642	118	760	190	484½	90½	575
625	115	740	185	472	87½	559½
608	112	720	180	459	85	544
591	109	700	175	446	83	529
574	106	680	170	433½	80½	514
557	103	660	165	421	78	499
540	100	640	160	408	76	484

For the Dodecagon.

Interior length	Addition to the length	Greater diameter	Exterior ſide	Interior breadth	Addition to the breadth	Leſſer diameter
fathoms						
744	95	839	190	539½	94½	634
724½	92½	817	185	525	92	617½
705	90	795	180	511	90	601
685½	87½	773	175	497	87	584½
666	85	751	170	482½	85½	568
646	83	729	165	468½	82½	551
626½	80½	707	160	454	80½	534½

Note 1. That this table is calculated with a ſuppoſition, that the angle of a baſtion is always to be placed on one of the extremities of the leſſer diameter, which is eaſily done, by ſetting the exterior ſide in the circumference of the oval, beginning at one of the ſaid extremities.

We think this ought always to be the practice to avoid having baſtions on the greater diameter, where the angle muſt be more acute than any where elſe.

Of all polygons there will be, according to this method, but the octogon and the dodecagon, that can have their

their baſtions on this diameter, whoſe interior length in this caſe will be, from the center of the demigorges of one baſtion to the center of the demigorges of the oppoſite one. We might even have done otherwiſe; but we thought it beſt to vary as little as may be from the general rule; for do what you can in theſe caſes, you muſt always have ſome baſtions as acute as thoſe you would avoid.

In all the other polygons, the interior length is contained between the two oppoſite curtins, to each of which it is perpendicular in polygons that have an even number of baſtions, but oblique in thoſe that have got an odd number. The interior breadth in even polygons is contained between the center of the demigorges of one baſtion, and the center of the demigorges of the oppoſite one; but in odd polygons, it is between the center of the demigorges of a baſtion, and the curtin that is oppoſite to that baſtion.

Note 2. That we have ſet down in this table only the interior lengths that belong to regular exterior ſides, that are from 190 to 160 fathoms. But if an interior length were required anſwerable to a ſide greater or leſs, this is eaſily done by the *rule of three*. Suppoſe, for inſtance, an interior length were required, anſwering the exterior ſide of 210 fathoms in a decagon; take the exterior ſide 190, and its correſponding interior length 554, and ſay, if 190 give 554, what will 210 give? and the anſwer will be 612 for the interior length belonging to the ſide 210. You need not even make uſe of this rule, only look into the table and obſerve by how much the interior lengths of the decagon increaſe in proportion as the exterior ſides increaſe by 5; thus having found that in this caſe the augmentation of the lengths is 14 fathoms and a half, you

muſt add four times 14 fathoms and a half, that is, 58 fathoms, to the length 554, becauſe the ſide 210 exceeds the ſide 190 by four times 5, *i. e.* 20; ſo that the ſame length, 612, would be found out this way, becauſe 554 + 58 = 612. Hence tis plain what method is to be made uſe of for finding an interior length, proportional to an exterior ſide leſs than 160; as alſo for finding the addition to that length, the greater diameter, the leſſer one, the interior breadth, &c.

Note 3. That the exterior ſides in this table exceeding one another by five fathoms, there can be had in the table only ſuch interior lengths as correſpond with them. But if you wanted an interior length belonging to an exterior ſide of an intermediate length, this alſo is found out by the *rule of three*, or elſe in the following manner; as for example, ſuppoſe an interior length were required belonging to an interior ſide 188 in an undecagon; this being between 190 and 185, take the interior lengths 642 and 625 correſponding with theſe two ſides, which lengths exceed one another ſo many times 17 as the ſides do one another by five, and add to the leſſer three-fifths of 17, *i. e.* 10 fathoms, and a little more; for 188 exceeds 185 by 3, which is three-fifths of 5; thus the interior length will be found to be 135, which might alſo be had by the *rule of three*; and ſo of other intermediate numbers.

This table is of the greateſt uſe in practice, and ſaves one the trouble of many calculations which muſt otherwiſe neceſſarily be made in fortifying either new places, where the interior length is already determined, or old ones, when the length cannot well be altered without leſſening their areas or interior contents. For inſtance, ſuppoſe the interior length of a place to be fortified were 574 fathoms,

it

it would immediately appear in the table that this length belongs to an undecagon, whoſe exterior ſide is 170 fathoms, that 106 fathoms are to be added to this length to make out the greater diameter, which conſequently will be 680 fathoms; that the interior breadth is 433 fathoms and a half, which added to 80 fathoms and a half, gives the leſſer diameter 514; ſo that taking a line of 680 parts for the greater diameter, an oval may be made in the aboveſaid manner; and laying 170 parts of this line eleven times in the circumference, you'll have a polygon within, which you may fortify as uſual.

If the given length is not to be met with in the table, being an intermediate one, as is 549, for inſtance, which is between the lengths 554 and 539 fathoms and a half of the decagon, the interior ſide belonging to that length, the addition and great diameter might be found, either by the *rule of three*, or in the manner before mentioned.

If the interior length ſhould belong to two polygons, as is 436 which belongs to an enneagon, whoſe exterior ſide is 165 fathoms, and is alſo the intermediate between the lengths 430 and 442 of the octogon, whoſe exterior ſides are 185 and 180, you ſhould then prefer the polygon that would give a ſide that comes neareſt to 180; and as the octogon has 182 fathoms and a half for the exterior ſide of the interior length 436, and the enneagon has but 165, you'll chooſe the octogon, and in order to deſcribe it (according to the method above-mentioned) find the great diameter, which in the octogon anſwers to the interior length 436.

What we have hitherto ſaid ſuppoſes, that we are never ſtraitened for breadth, and that the oval may always be deſcribed in the manner we have ſaid, ſo as that the little diameter may be to the great one as 31 is to 41, and that

the radius of the circle which paſſes through the extremity of the great diameter may be to the half of the little diameter as 13 two-thirds is to 15 one-half, or (to avoid fractions) as 82 is to 93. But were we ſtraitened for breadth as well as for length, then either the length and breadth would belong to the ſame ſide of a polygon, or the length would belong to one ſide and breadth to another of the ſame polygon; or laſtly, when one belongs to one ſide of one polygon, the other would belong to the ſide of another. The firſt of theſe caſes 'tis evident has no difficulty in it, let us examine the other two; and for this, the three laſt columns of our table will be very uſeful. As for the ſecond caſe; ſuppoſe that the interior length be 442, which belongs to the interior ſide 185 of the octogon, and that the interior breadth is 276, which belongs to the outward ſide 165 of the ſame octogon; we give to both the addition our table exhibits, *i. e.* 103 fathoms for the length, and 91 for the breadth, which gives us 545 fathoms for the greater diameter, and 367 for the little one.

We draw upon the paper a line A B, which we divide in 545 parts for the great diameter; in the middle of that line we raiſe a perpendicular C D, which is of each ſide 183 fathoms and a half, which makes 367 fathoms for the
Fig. 9. whole little diameter; this done, as we know that in a common oval the half of the little diameter is to the radius of the circle which paſſes through the extremity of the great diameter as 93 is to 82, we make uſe of the *rule of three*, and ſay, 93 is to 82 as 183 fathoms and a half, which is the half of our little diameter, is to the number which we are to find, and this number will come out 160, which we lay on the extremities of our great diameter from A to E, and from B to F; or elſe, without uſing the *rule of three*, we take with the compaſſes the half of the little diameter,

meter, and open the ſector, ſo that the two points of the compaſſes fall upon the two points 93 of either ſide of the line of the equal parts; then leaving the ſector opened in this manner, we take with the compaſſes the diſtance of 82 to 82 upon the ſame line of the equal parts, and lay that diſtance on the extremities of the great diameter from A to E, and from B to F; after that, from the points E and F, taken for the centers, we deſcribe the circles HAG, IBL, upon which we lay of either ſide the height of the radius E A from B to I and from B to L, from A to G and from A to H; then from the points GHIL we draw lines, which paſſing through the centers E, F will give at the points O O of their meeting the centers O O, whence we ſhall deſcribe the arches GDI, HCL, which will finiſh our oval for us. We ſhall ſhew in the third caſe how we muſt do when the circle drawn from the center O does not paſs thro' the extremity of the little diameter.

When the oval is thus drawn, we find in the table that the great diameter belongs to the ſide 185 of the octogon, and that the little one belongs to the ſide 165 of the ſame octogon; wherefore we take a mean between 185 and 165, *i. e.* 175 fathoms, we lay theſe 175 fathoms on the circumference of the oval, which they'll divide into eight equal parts, and join all the points of diviſion by right lines, which will be the exterior ſides of an octogon, which we ſhall fortify within according to the uſual method.

If the length or breadth were not to be found in the table, then thoſe two lengths, or thoſe two breadths of the table muſt be ſought for between which the length or breadth given happens to be; and the addition muſt be found in order to obtain the great or little diameter, either by the *rule of three*, or in the method that has been ſhewn before,

before, the which, upon every occaſion, muſt be well obſerved, and therefore we ſhall not repeat it.

As for the third caſe, that is, when the interior length belongs to one polygon, the interior breadth belongs to another. Suppoſe that the length be 340, which belongs to the exterior ſide 190 of the heptagon, and that the breadth be 268 which belongs to the exterior ſide 160 of the octogon; we firſt conſider if the length be not intermediate between ſome of the octogon's lengths, that the length and breadth may belong to the ſame polygon, and as we find that it is not, we examine further if the breadth be not intermediate between ſome of the heptagon's breadths, and finding that it is between 267 and 274, we look (according to the before-mentioned rules) for the addition, and for the exterior ſide of the heptagon which belongs to it; this done, we give the additions proper for its length and breadth; we draw our oval, and finiſh the reſt of it according to the foregoing caſe.

But if the length and breadth cannot be reduced to the ſame polygon, as the length, for inſtance, 454, which belongs to the ſide 190 of the octogon, and breadth 198 which belongs to the exterior ſide 170 of the hexagon, we then give to the length, the addition 105, as it is marked in the table, which makes 559 fathoms for the great diameter; and to the breadth, the addition of 94 fathoms and a half, as it is in the table, which makes 292 fathoms and
Fig. 10. a half for the little diameter; then we look for the radius A E of the circle that ſhould paſs through the extremity of the great diameter, in the ſame manner as in the foregoing caſe; and having deſcribed the arches L A I, G B H, we lay on either ſide of them the length of the radius from A to I, from A to L, from B to G, and from B to H; we then draw the lines I E O, G F O, and ſeeing that the

circle

circle we ſhould deſcribe from the point O of their meeting would indeed paſs through the points I G, but not through the extremity of the little diameter, we look for the true center that paſſes through theſe three points, and this I do in the following manner. We draw from the extremities of the little diameter, right lines to the points I G. We divide the lines D I, D G, equally in two at the points M N, and upon the points M N raiſe two perpendiculars within, which we lengthen until they meet; the point of their meeting is not marked in the plate, becauſe we had not room enough for it. We take this point of meeting for our center, and from that center deſcribe the arch I D G, which paſſes by the points I G, and at the extremity of the little diameter. We do the ſame thing on the other ſide to have the arch L C H, and by this means our oval is finiſhed. Indeed it might have been deſcribed more geometrically; but then the radius A E muſt have been diminiſhed, which would occaſion the arch A L to be leſs, and the baſtions erected upon it too acute.

The oval being thus made, the ſhorteſt way to find out its proper polygon, without entering into troubleſome and elaborate calculations, is to take with the compaſs 180 fathoms, and to lay them as many times on the oval's circumference as they will go; if they go preciſely a certain number of times, as ſeven or eight, the polygon will be an heptagon, or an octogon; ſhould any thing remain, the opening of the compaſs muſt be increaſed or diminiſhed until it comes exact; but care muſt be taken that if in diminiſhing 15 fathoms, for inſtance, an octogon was found, and increaſing only by 10 an heptagon was found, to give the preference to the latter of theſe; partly, becauſe the ſides of an heptagon having 190 fathoms, would be leſs diſtant from 180 than thoſe of the octogon, which would

would have but 165; and becauſe it would ſave the expence of a baſtion.

Should the angles of the baſtions which are towards the extremity of the great diameter, become too acute, we ſhould allow the perpendicular, at the extremity of which the lines of defence ſhould be drawn but a ſeventh part of the exterior ſide, or even an eighth, were it neceſſary.

To fortify a long ſide.

AS the long ſides do not always permit that the line of defence be within musket-ſhot, notwithſtanding the flat baſtions that might be erected in their middle, the ancient authors, to ſupply this defect, put redans between the baſtions that were made up of a flanc D C and face C E, ſuch as the twelfth figure here exhibits. They were ſometimes increaſed, as in figure 13, and then the work was called *ſaw* work, becauſe in fact it is like the teeth of a ſaw. But theſe ſort of works were very inconvenient, by reaſon of their little extent, and withal had this diſadvantage, that it offered the enemy a dead angle, that is, the beſieged could not ſee from any part of the place, ſo that miners might very ſafely approach it, as the angle E, *fig.* 12. Wherefore that ſort of fortification is now univerſally rejected, and the following is the method made uſe of, according to the rules which M. *de Vauban* himſelf frequently practiſed.

Fig. 12, 13.

A long ſide may be either from 200 fathoms to 240, or even 250; or from 250 to 300; or laſtly, from 300 as far as 400, 500, *&c.*

In the firſt caſe, that is, if the long ſide be from 200 fathoms to 240 or 250, it muſt be fortified as it is, eſpecially if

if it is upon a river or marſh, where the approaches are difficult; but care muſt be taken that the perpendicular, at the extremity of which the line of defence is drawn, is allowed but the eighth part, or even the ninth, tenth, &c. of the exterior ſide, that the flanked angles may not be too acute. And as then the flancs become ſmall, and beſides the line of defence not within musket-ſhot, this is ſupplied, *firſt*, by a good battery, which is placed in the middle of the curtin; *ſecondly*, by the out-works, that are greater or leſs, according as the ſituation is.

The plan of *Huningen*, which we have here given you entire, we think is a complete model in its kind. Fig. 11.

Huningen is a fortreſs ſituated upon the *Rhine* a little above *Baſil*. Its long ſide is upon the river. M. *de Vauban* who fortified it, has omitted nothing to make it ſecure againſt the danger of being taken by ſtorm or ſurprize.

The firſt thing that is ſeen on the other ſide of the *Rhine* is a great horn-work, with a half-moon before the curtin, and a counter-guard on the ſide of each wing. Theſe works have a large foſsè round them of about 20 fathoms broad, that communicates with the *Rhine*. Much about the middle of the river is another horn-work which is larger, and enfilades all the foſsès of the firſt.

Upon the border of the *Rhine*, on the ſide of the fortreſs, is found a ſort of covert-way longer than the front of the place. There is a baſtion in the middle to defend the paſſage of the *Rhine*. Of all ſides, and at each end, there are two ſluices or dams to keep the water in their proper foſsès, that they may not be dried up when the river falls. This covert-way is ſeparated from the body of the place by a good foſsè, where there is a double ra-

velin over-againſt the middle of the curtin, and a double tenail for the ſmall arms. The reſt of the place on the ſide of land is fortified with no leſs care, as the plan ſhews. It is to be remarked how careful the author has been to occupy the poſts which might be troubleſome, by horn-works, to draw there the water from the *Rhine* by a canal, which in the mean time ſerves as an avant-foſsè to the place, and at the head of which he has put an out-work or horſe-ſhoe to hinder the enemy from attempting to ſtop the water by a dam; and laſtly, to put a counter-guard before the baſtion where there is no horn-work, that by this means the force of every ſide may be nearly equal.

'Tis aſtoniſhing that M. *de Coehorn*, who was unqueſtionably a very great man, has yet ſlighted this piece of fortification, as he has done in his book. This author, in the chapter where he treats of the manner of fortifying places ſituate upon a river, gives us a bad plan, which he calls a *french* one, wherein the long ſide is fortified, but by two bad redans, which he finds fault with, and with reaſon; but adds, that this plan differs but little from *Huningen*'s, which he has ſeen, he ſays, at a virtuoſo's, excepting that this here had a falſe-bray, which we call a tenail, and a horn-work. Why could he not ſee, that his exception did not contain the half of what it ought; and that beſides the tenail and horn-work, there was yet a baſtion at each extremity of the long ſide, a double ravelin or covert-way, with its dykes; another horn-work in the middle of the river, and counter-guards to the wings of that which is upon the border of the *Rhine?* It muſt certainly be, either that he has been ſhewn a falſe plan of *Huningen*'s, by one of thoſe bad virtuoſo's who collect whatever offers itſelf to them, without choice and a proper judgment; or that if he has been ſhewn the true plan, his

his prepoſſeſſion, ever uſual to him againſt every thing that came from M. *de Vauban*, has, if it may be ſaid, bewitched his eye-ſight; and this appears to us to be ſo much the more true or certain, as he has himſelf copied the work of the dyke, aſſuming to himſelf the honour of its invention, without perceiving that thoſe who would ſee *Huningen*, or his plan, would directly think that he has taken it from thence, ſince he has ſeen that fortification. Beſides, his long ſide, in the manner he fortifies it, is not by far ſo ſtrong as that which he has ſo much found fault with.

There is but one detached baſtion upon the middle, between the dyke and rampart; and of each ſide of this baſtion, a demi-baſtion, with orillons fixed to the rampart, and whoſe flancs are turned ſome towards the middle of the long ſide, and the others towards the extremities that are in a right line.

The place on the land-ſide is fortified according to his ſecond method, which has been ſpoken of; we have not here inſerted his plan, which is to be ſeen in his book, being unwilling, without a neceſſity, to multiply our plates.

If the long ſide be between 240 to 300 fathoms, as is the ſide A B, you then with the compaſſes take 180 fathoms, and laying one of the feet firſt on the extreme point A, and then on the other B, you deſcribe two arches which cut one another in C, and draw the lines A C, C B, which you fortify in the common way; this is called *fortifying by the ſubtenſe*. This method alſo may be uſed when the long ſide having 200, 210 fathoms, &c. has before it a plain upon which it may be extended. Fig. 15.

Laſtly, when the long ſide has 300 fathoms and upwards, as has the ſide A B; it is divided into two equal parts to the point C, and each of theſe parts A C, C B, Fig. 14.

is fortified after the common way, which gives a flat baſtion towards the middle, called a *moineau*. This baſtion is called a *flat one* becauſe it is made upon a right line, and not upon an angle. If the long ſide were ſo long that it could be divided into three, four parts, each of which would have at leaſt 150 fathoms, it might be divided into thoſe parts which might be fortified, as is juſt ſaid, which would give two or three baſtions, in proportion to the length of the ſide.

A way how to deſcribe a regular place with a long ſide.

THERE are many new places built in this manner, as is *Huningen*, *Saar-Louis*, *Ath*, &c. You firſt draw a circle, in which you inſcribe the polygon that is wanted, each ſide to have 180 fathoms, as is the circle A B C D E F G H, in which an octogon is inſcribed. You take off three ſides of that polygon by a line G D, called the *ſubtenſe*; the ſame is to be done in all the other polygons, whatever number of ſides they have, *i. e.* three ſides muſt always be taken off. The ſubtenſe is divided into two equal parts to the point S, and if you give the great ſide 200 fathoms, for inſtance you lay half of it, *i. e.* 100 of each ſide of the point S, from S to M and from S to N. You raiſe upon the points M N two indefinite perpendiculars M R, N Q; then with the compaſſes take 180 fathoms, and ſetting one foot on the extreme point D of the ſubtenſe, deſcribe with the other an arch which cuts the perpendicular N Q in the point Q, and draw a line Q D; in the ſame manner you ſet the compaſſes at the other extreme point G of the ſubtenſe, and with the ſame opening of 180 fathoms, deſcribe an arch which cuts the perpendicular M R to the point R, and draw the line

Fig. 16.

line G R, which will be one ſide of the polygon; as alſo the line Q D; laſtly, you draw the line R Q, which will be a long ſide of 200 fathoms.

The other ſides muſt be fortified according to the uſual method; and for the long ſide you muſt give the perpendicular but the eighth, or even the ninth, tenth, &c. at the extremity of which the lines of defence muſt paſs.

This ſuppoſes that we are at liberty to inſcribe in the circle what polygons we pleaſe, and may give the great ſide what length we will, the which may poſſibly happen in the building of new places; but were we to fortify an old one, whoſe great interior ſide was determined, and whoſe interior figure could be but very little altered, as it could only be enlarged on all its ſides, it might then be done in the following manner.

Suppoſe we had an irregular place to fortify: A B C D E F G H I L M, which we are at liberty to enlarge, but without touching the great ſide I H, which is upon the border of a river. We firſt take the interior breadth A F of that place; we deſcribe a circle upon that breadth taken for the diameter; then having divided the diameter into as many parts as it has fathoms, we take in the table of exterior and interior ſides ſome of the interiors correſponding to the exterior of 180 fathoms, and that may be inſcribed in this circle a certain number of times; but if there be none, we chooſe one which will require leſs to be added to or taken from it, that all may come right. The interior polygon thus found, we look for its exterior ſides by the means of the ſame table, and deſcribe our exterior polygon; the exterior polygon will be found with more eaſe by the following table, which ſhews which is the exterior polygon that belongs to ſuch an interior diameter, what is the

Fig. 17.

the length of its ſides and that of the exterior diameter, as we ſhall ſhew when we come to explain it.

Having found then, either one way or other, the exterior polygon, we cut off three of its ſides by a ſubtenſe, which we divide equally in two. At the middle of the ſubtenſe we lay half of the great ſide each way; we raiſe two indefinite perpendiculars, and finiſh our plan as before; obſerving however to give the great ſide, which is here exterior, a length correſponding to the great interior ſide of the place which I am to fortify; the which is eaſily done by the help of the table of the exterior and interior ſides.

This plan is not that of the place which we have to fortify; but it ſerves us for a model. Suppoſe, for inſtance, that *fig.* 16. were the plan or model we had juſt finiſhed. At the middle of the curtin of the great ſide we draw a line V T that paſſes through the center of the circle, and cuts the circumference at the oppoſite point T; this line is always perpendicular to the great curtin; when the polygon is even it cuts the oppoſite curtin equally in two, and when it is uneven it paſſes through the point of a baſtion. This being done, we draw upon the paper where we intend to deſcribe our plan, the great ſide of the irregular place, or elſe work upon the very plan of that place, cutting its great interior ſide I H equally in two to the
Fig. 17. point P; at the point P we raiſe an indefinite perpendicular P X; we take upon the plan which we uſe as a model, the part V S of the perpendicular contained within the great curtin and the ſubtenſe, and lay that part upon our plan from P to Q, through which we draw our ſubtenſe R Q T parallel to the great ſide; we make that ſubtenſe equal to that in the model, and in the ſame model we take the

part

part SO of the perpendicular contained within the ſubtenſe and center of the circle, and having laid that part upon our plan from Q to O, and made the part OX equal to the part OT of the model, we deſcribe from the center O the great arch of the circle RXT, that terminates of either ſide of the ſubtenſe, and in which we inſcribe the five exterior ſides that ſhould be contained in them. In order to have the other three, we make upon our ſubtenſe the ſame diviſions as that of the model has; upon theſe diviſions we raiſe perpendiculars, and finiſh the reſt as before.

It may ſometimes happen that the great ſide of the model will be too near the place's center, ſo as to make us extend too far in the ground oppoſite to the great ſide, and at the ſame time cut off ſome of the extent of the town towards the collateral ſides that are at the extremities of the ſubtenſe; but in this caſe, inſtead of a circle, an oval muſt be made, whoſe great diameter may be parallel to the great ſide.

Suppoſe we had the irregular place ABCDEFGHI LM to fortify, whoſe ſide AB lies on the border of a river, and whoſe ſituation is ſuch, that if we wanted to incloſe it in a circle, we muſt advance too far towards the plain on one ſide, and on the other cut the incloſure of the town towards the points LE; we take the length LE which is parallel to the great ſide, and then drawing it upon another paper in order to make our model upon it, we look into the table laid down when we ſpoke of the oval for the addition we muſt give that length to have the great diameter. The addition thus made, we deſcribe our oval upon that diameter, as is ſeen in *fig.* 19. According to the ſame table we find out the polygon that belongs to it, as alſo how large the interior ſides are. But as we muſt take off three of theſe ſides by a ſubtenſe which muſt be parallel to the

Fig. 20.

Fig. 19.

the great ſide, which we could not do, if there were the point of a baſtion at the extremity of the little diameter where we ſhould place the great ſide, we alter the ſituation of the ſides into the oval, if the polygon is even, becauſe thoſe only have always the point of a baſtion at each extremity of the leſſer diameter. *Fig.* 18. is deſcribed to ſhew how this alteration can be made. The line B O repreſents the leſſer diameter of an oval; the lines A B, B D, ſhew two exterior ſides of an even polygon inſcribed in an oval; and it is obſervable, that in cutting the arches A B, B D, in two equal parts to the points E C, the line E C would be equal to one of the exterior ſides, and ſo all we have to do is to lay the exterior ſide upon the circumference from the point E or C, to alter the ſituation of our figure, in order that the flanked angles may correſpond to the ſame points to which the middle of the ſides did before, and that by conſequence the middle of the ſides would correſpond to the ſame points where the flanked angles did.

When our ſides then are thus placed upon the oval, we
Fig. 19. cut off three of them by a ſubtenſe, which we divide equally into two; and having found out by the table of interior and exterior ſides the length that muſt be given to an exterior ſide, when the interior is equal to the great one A B of the place which we are to fortify, we lay the half of that length from the middle of the ſubtenſe either way; we raiſe two perpendiculars, as in the figure, and taking in our compaſſes the length of one of the ſides deſcribed upon the oval, we ſet one foot at the extreme points of the ſubtenſe, and with the other deſcribe an arch that cuts the perpendicular, and finiſh the reſt of it as before.

Our model thus finiſhed, we return to that which we
Fig. 20. have to fortify, and divide its great ſide A B into two equal parts, then raiſe at the middle of it an indefinite perpendicular;

dicular; we take in the model the diſtance from the middle of the great curtin to the oppoſite extremity of the little diameter, and transfer that length upon the perpendicular; we mark the diſtance from the curtin to the great diameter and to the ſubtenſe, both which we draw equal to thoſe in the model; we likewiſe mark upon the greater and leſſer diameter the centers X Y of the leſſer circles, and the center of the greater circle; after this we deſcribe the part R T S of the oval, in which we inſcribe the ſides that ſhould be contained within it; laſtly, we finiſh the other three by following the dimenſions of the model, and fortify thoſe ſides in the manner aforeſaid, as may be ſeen in *fig* 20. All this might equally have been done, had the oval more length and leſs breadth.

What we have been ſaying of the circle and the oval, will be better underſtood by examples, which we ſhall ſoon give, where we ſhall determine the length of the great ſide and that of the place, which we have not as yet done; and, that there may be nothing wanting, ſhall ſhew at the ſame time what muſt be done when the great ſide is ſo long, as that we muſt neceſſarily put a flat baſtion upon its middle. But we muſt firſt give you the table that we have promiſed above, the which will make this practice very eaſy in reference to the circle.

A table to find out the length and number of exterior sides, the length of the greater radius, and the capital, the lesser radius being given.

For the Square				For the Pentagon				For the Hexagon			
Lesser Radius	Capital	Greater Radius	Exterior side	Lesser Radius	Capital	Greater Radius	Exterior side	Lesser Radius	Capital	Greater Radius	Exterior side
90	51	141	200	119	51	170	200	144½	55½	200	200
88	49½	137½	195	116	50	166	195	141	54	195	195
85½	48½	134	190	113	48½	161½	190	137	53	190	190
83	47½	130½	185	110	47	157	185	133½	51½	185	185
81	46	127	180	107	46	153	180	130	50	180	180
79	44½	123½	175	104	45	149	175	126½	48½	175	175
76½	43½	120	170	101	43½	144½	170	123	47	170	170
74	42½	116½	165	98	42	140	165	119	46	165	165
72	41	113	160	95	41	136	160	115½	44½	160	160

For the Heptagon				For the Octogon				For the Enneagon			
Lesser Radius	Capital	Greater Radius	Exterior side	Lesser Radius	Capital	Greater Radius	Exterior side	Lesser Radius	Capital	Greater Radius	Exterior side
178	52	230	200	210	51	261	200	242	50	292	200
173½	50½	224	195	205	49½	254½	195	236	49	285	195
169	49½	218½	190	199½	48½	243	190	230	48	278	190
164½	48½	213	185	194	47½	241½	185	224	46½	270½	185
160	47	207	180	189	46	235	180	218	45	263	180
155½	45½	201	175	184	44½	228½	175	212	44	256	175
151	44½	195½	170	178¾	43½	222	170	206	42½	248½	170
146½	43½	190	165	173	42½	215½	165	200	41	241	165
142	42	184	160	168	41	209	160	194	40	234	160

For the Decagon				For the Undecagon				For the Dodecagon			
Lesser Radius	Capital	Greater Radius	Exterior side	Lesser Radius	Capital	Greater Radius	Exterior side	Lesser Radius	Capital	Greater Radius	Exterior side
274½	48½	323	200	305½	49	354½	200	337	49	386	200
268	47	315	195	298	47½	345½	195	329	47½	376½	195
261	46	307	190	290½	46½	337	190	320½	46½	367	190
254	45	299	185	282½	45½	328	185	212	45	357	185
247	44	291	180	275	44	319	180	303½	44	347½	180
240	43	283	175	267½	42½	310	175	295	43	338	175
233	42	275	170	259½	41½	301	170	286½	41½	328	170
226½	40½	267	165	252	40½	292½	165	278	40½	318½	165
219½	39½	259	160	244½	39	283½	160	270	38½	308½	160

The firſt column of this table exhibits the leſſer radius of the polygons that are proportional to the different lengths that their exterior ſides may have; the ſecond ſhews the capitals; the third, the great radius; and the fourth, the outward ſides: but as theſe ſides are only from 160 to 200, and exceed one another by 5; if it were required to find leſſer diameters, or capitals, or laſtly greater diameters for ſides greater or leſs than, or intermediate between thoſe in the table; the ſame method muſt be made uſe of for finding them as was ſhewn for the foregoing tables in like caſes, which need not be repeated here.

This table may be of great uſe in practice; for ſuppoſe a new place were to be built, whoſe interior diameter may be taken at pleaſure; or that an old one was to be made regular, without changing its diameter; this diameter muſt be divided into two equal parts, and its half being the interior radius, we ſhould immediately ſee in the table what ſort of polygon would be fitting for the place, what would be the length of its diameter, and that of its ſides; but it muſt be obſerved, that as the leſſer radius can belong to two different polygons, which often happens, we muſt always chooſe that which gives exterior ſides neareſt to 180; and if one gives as much under 180 as the other gives them above; for inſtance, if one gave ſides of 170, and the other 190, we muſt always chooſe the greateſt preferably to the leaſt, becauſe beſides the expence that is ſaved, we ſhall have greater and much larger baſtions; however, very few of the ſides muſt be allowed 200, or even 195, becauſe in this caſe the line of defence would exceed the length of musket-ſhot. All this will appear more evident by the following examples, where we ſhall ſhew at the ſame time what is to be done when the great ſide is ſo long that we are obliged to erect a flat baſtion upon its middle.

Suppoſe then we had the irregular place ABCDEFGHI to fortify, which we may make regular of all ſides, pro-
Fig. 22. vided we do not alter the long ſide AB, which is upon the border of a river; we take the greateſt breadth of the town, which is from H to D, and finding that that breadth is, for inſtance, 448 fathoms, we take the half, 224, which we conſider as an interior radius. We examine in the table to what polygon that interior radius belongs; and finding that it may be applied to a decagon whoſe exterior ſide is about 164 fathoms, and to an enneagon whoſe exterior ſide is 185, we chooſe the latter, becauſe it comes neareſt to 180; wherefore we give to the radius 224, the increaſe of 46 fathoms and a half, for the capital, as the table exhibits it, and have 270 fathoms and a half for our great radius, which we draw upon another paper to make
Fig. 21. a model. We deſcribe a circle upon that great radius, and taking 185 fathoms with the compaſs, we lay it nine times on the circumference, which gives us an enneagon.

We then return to the plan we have to fortify, and finding that its long ſide AB, which we conſider as an interior, is about 306 fathoms, we take the half, 153, and the foregoing table of interior and exterior ſides ſhews us that an interior of 153, applied to an enneagon, has for its exterior ſide 185, whence we know that our long exterior ſide can be divided into two, and each of them will have 180 fathoms. Wherefore returning to our model, we cut off by a ſubtenſe AB four of its ſides, becauſe our long ſide ſhould be equal to two of them, which, joined with the two collaterals AF, BH, will give us the four which we cut off. We divide that ſubtenſe into two equal parts to the point C; we lay on either ſide of it from C to E, and from C to D, half of our long exterior ſide, *i. e.* 185 fathoms. We raiſe the perpendiclars DH, EF, and

and from the extreme points A, B, of the ſubtenſe, deſcribe the arches that cut the perpendiculars with an interval of 185 fathoms, becauſe the other ſides of the polygon are of that length; then we join the points of interſection F, H, by a right line F H, which we biſſect, and fortify as two ſides. The figure ſhews the reſt.

This model being made, we draw its long interior ſide P Q, which being equal to that of the place we have to fortify, we divide equally into two to the point S, and upon that point S raiſe the perpendicular S R, which paſſing through the center, cuts the circumference at the oppoſite point R; we then return to the plan of our place, and having biſſected its long interior ſide A B at the point M, and raiſed the indefinite perpendicular M P, we lay upon that perpendicular the diſtances of the center, ſubtenſe, and circumference, as they are in the model; then having drawn our ſubtenſe T V parallel to the long ſide, and equal to that of the model, we deſcribe the great arch of the circle T P V, in which we inſcribe the five exterior ſides that ſhould be included in it. Laſtly, we find the other four by marking the diſtances N X, N Y, equal to thoſe of the model, by raiſing the perpendiculars, &c. If the flanked angles which are at each extremity ſhould be too acute, you muſt diminiſh your perpendicular through the extremity of which the lines of defence do paſs, as we have ſaid elſewhere, and make amends for the ſmallneſs of the flancs with ſome out-works. 'Tis eaſily ſeen, without any particular remark upon it, that the places which have a long ſide of this ſort ſhould have eight or ſeven baſtions at leaſt. Fig. 21. Fig. 22.

Now let us ſuppoſe that the place to be fortified is longer than broad, ſo that it cannot be made regular but by an oval, as is the A B C D E F G H, whoſe long ſide Fig. 24.

ſide is about 310 fathoms. We take the greateſt length of that place, which is the diſtance from H to C, this length being of 525 fathoms, we find in the forementioned table of the greater and leſſer diameters of the oval, that it belongs to a decagon, whoſe exterior ſide is 180 fathoms, and that its great diameter muſt be 665; wherefore we add 140 fathoms to the length 525, as the table ſhews, and lay that line, which will be 665 fathoms,
Fig. 23. upon another paper, which is to ſerve us for a model; we divide that line into three equal parts; we deſcribe our oval as uſual, and inſcribe a decagon in it by taking with the compaſſes 180 fathoms, which we lay ten times on the oval's circumference. Here care muſt be taken, that there be always a flanked angle at the extremity of the leſſer radius, that the ſubtenſe which cuts the four ſides may be parallel to the great ſide the plan is to have; which is eaſily done, if you always begin to inſcribe the polygon at the extremity of the leſſer radius, as we have ſaid when we explained the table of the ovals.

The polygon thus inſcribed, we return to the plan we
Fig. 24. have to fortify; and as its long ſide A B, which we conſider as an interior one, is 310 fathoms, we take the half, 155, and find in the table of interior and exterior ſides, that it belongs to a decagon, whoſe exterior ſide is 182 fathoms, whence we know that our whole exterior ſide will be twice as much, and that we muſt therefore make a flat baſtion in the middle of it; wherefore returning to our model, we cut off four ſides by a ſubtenſe parallel to the great diameter. We divide it equally into two to the
Fig. 23. point C; we lay of either ſide of it, from C to D, and from C to E, 182 fathoms, which is half of my long exterior ſide; we raiſe perpendiculars, and finiſh the reſt of it as the figure expreſſes it; remembering only to draw the long

long interior ſide H I, which will be found equal to that of the place which we are to fortify.

Having thus made our model, we divide the long ſide A B into two equal parts at the point R; upon that point we raiſe an indefinite perpendicular, upon which, when we have laid the diſtances of the oppoſite extremity of the leſſer diameter, of the ſubtenſe, and greater diameter, we draw the greater diameter and ſubtenſe equal to thoſe in the model. We mark alſo upon the greater and leſſer diameter the centers P, Q, ſome little circles, and the center M of the great arch; afterwards we deſcribe the great portion of the oval X V Y, and finiſh the reſt as before. Fig. 24.

What has been ſaid may be eaſily practiſed upon ovals that are prolonged, which we have elſewhere ſpoken of, without being obliged to give any examples of it. But as it is poſſible that a place which has a long interior ſide correſponding to an exterior of 200 or 240 fathoms may extend itſelf towards the oppoſite ſide, ſo as that it ſhould be included within an oval, whoſe long diameter would be perpendicular to the long ſide, the following example ſhews how we muſt act in that caſe.

We muſt take the greateſt breadth of the place, parallel to the long ſide; and, in the table of ovals, find out to what polygon that interior breadth belongs, and what ought to be the length of the exterior ſides, that of the leſſer and greater diameter; wherefore having given to the breadth the addition that the ſame table exhibits, divide it equally into two, and through the middle of it draw a perpendicular equal to the greater diameter, that it may be divided equally into two by the leſſer diameter. This done, divide the greater diameter into three, and deſcribe the oval in the uſual method. Fig. 25.

Then,

Then, if the polygon belonging to it were uneven, begin to lay the ſides on the circumference, at the extremity of the greater diameter, oppoſite to the great ſide; if it were an hexagon or decagon, begin at the extremity of the leſſer diameter; but if it were an octogon or a dodecagon, do as was directed in *fig.* 18. ſo that the greater diameter may always fall on the middle of the curtin towards the great ſide, that the ſubtenſe, which in this caſe is to cut off but three ſides, may be parallel to the long ſide of the place. Having thus inſcribed its polygon, as the octogon of *fig.* 25, whoſe ſides we ſuppoſe to be 180 fathoms, three ſides muſt be cut off by a ſubtenſe C D parallel to the leſſer diameter; that ſubtenſe muſt be divided equally into two at the point G; lay on either ſide half of the exterior ſide correſponding to the interior one given, raiſe the two perpendiculars H E, L F, and the model to be made uſe of will be finiſhed as uſual, as we have ſaid before.

We have enlarged upon this and the preceding article, the rather becauſe, we think, that there is ſcarce any irregular place but what may be reduced to ſome one of the above-mentioned figures with very little coſt, inſtead of adhering too ſcrupulouſly, as is ſometimes the caſe, to old circumferences, whoſe angles being either acute, or reentering, or whoſe ſides being either too great or too little, cauſe a much greater expence than that, one endeavours to avoid, and prevent their being ſo well fortified as they would be according to ſome one of the preceding directions; nevertheleſs, as there may be caſes where we muſt ſubmit to the great irregularity of ſome places, we ſhall ſee in what follows how thoſe places may be put into a ſtate of good defence.

To fortify a ſide that is too ſhort.

THOSE who fortify outwards, diminiſh the demi-gorges of the ſides that are too ſhort, ſo that the curtin may be 60 fathoms at leaſt, and even wholly cut them off if it be neceſſary, as when the little ſide has but 60 fathoms; then they raiſe their flancs at the extremity of the curtin, and draw the lines of defence razant, as was ſaid in explaining *fig.* 5; then they take the gorges from the collateral ſides, upon which they likewiſe raiſe their flancs, and determine the faces of either ſide by the lines of defence which cut the former at their flanked angles. This ſuppoſes that the collateral ſides are long enough to receive the whole gorge; but if they were not, or ſhould the little ſide be leſs than 60 fathoms, they then cut the little one off, either by lengthening the collateral ſides until they meet, provided they do not form an angle too acute; or, if they cannot do otherwiſe, by diminiſhing ſomewhat of the extent of the place.

This manner of fortifying is ſubject to very great inconveniencies, as we have elſewhere ſhewn; we will therefore endeavour to fortify inwards in all caſes, which we ſhall here explain in two examples; the firſt of which may be uſed for ſhort ſides and re-entering angles, and the ſecond for acute angles.

Suppoſe then we had an irregular place to fortify ABC DEFGHILM, *&c.* whoſe ſides AB, TS, GH, are too ſhort, and the angles P, M, I, D, are re-entering; we muſt neceſſarily correct the ſides that are too ſhort, for otherwiſe the curtins not being long enough, the cannon and musketeers of each flanc would not be able to diſcover half of it, by reaſon of the height of the rampart and Fig. 26.

thickneſs of the parapet, unleſs too great a ſlope were given to the embraſures and to the top of the parapet, which would weaken it very much; beſides that the cannon could be plunged but with very great difficulty at ſo ſmall a diſtance. We muſt alſo find ſome remedy for the re-entering angles, which, as they cannot defend themſelves (and therefore are called dead angles) would give the miner an opportunity of approaching them without being diſcovered. Wherefore we firſt look for the exterior ſides of all the ſides that are between two projecting or ſaillant angles, which are found by the help of the table of interior and exterior ſides which we have already given; or elſe, without giving ourſelves the trouble to know the value of our angles, we draw our exterior ſides without, more or leſs diſtant, as the interior ſides are greater or leſs; thus, as the table ſhews us that for an interior ſide of 160 fathoms and upwards, we can put the diſtance of 49, 50, or 51 fathoms for the exterior, we leſſen the diſtance proportionably as the interior ſides diminiſh; a few fathoms, more or leſs, ſignify but little, and we may add to or diminiſh their number, if by that we find that our fortification can be made better than it is. Our exterior ſides thus found, it happens, either that thoſe of the little ſides having gained upon the others are increaſed, without prejudice to thoſe that are next to them, or that by their increaſe they have ſhortened them too much.

If one exterior ſide be increaſed, without making the other two irregular, we then fortify theſe three ſides after the common way, giving the perpendicular through which the lines of defence paſs, the ſixth, ſeventh, or eighth part of the exterior ſide, according as the angle is more or leſs open. It is in this manner we fortify the three ſides V A, A B, B C. The middle one, A B, is become regular, though

though before it was too ſhort. If the exterior ſide cannot be enlarged without hurting its two collaterals, then it muſt be intirely taken off, and theſe muſt be lengthened until they meet, ſo that inſtead of three ſides there will be but two; and it is thus we have fortified the three ſides V T, T S, S R, which we have reduced to the two *a b*, *b c*. We have done the ſame with the little ſide G H; but if the two collateral ſides cannot be lengthened without becoming too long, in this caſe the place muſt be extended outwardly, until three ſides be had that are at leaſt 160 fathoms each, or reduced inwardly, 'till the two great ſides contain each of them 190 fathoms at moſt.

As for the re-entering angles, as the angle P, we do not look for the exterior ſide; but we take with the compaſſes 120 or 125 fathoms, which is the common diſtance of musket-ſhot, and fixing one foot at the extreme point X of the near exterior ſide, deſcribe with the other an arch that cuts the ſide Q P, at the point P, and we draw the line X P, upon which we take 50 or 52 fathoms for the face X *m*; we then draw the flanc *m r* upon the ſide Q P, and make it incline more or leſs as may be required; and as the line X P ends at the top of the re-entering angle, all on that ſide will be in good defence. We ſhould have done ſo on the other ſide P O, if it had been of the ſame length; but as it happens to be twice as long, we have made a flat baſtion in the middle of it by the means of the exterior ſide *s n*, which we have drawn from the extremity of the next exterior ſide. So then all the parts are within musket-ſhot, and the re-entering angle is well fortified.

If the ſide P O, which is too long to be within musket-ſhot, be not long enough to receive a baſtion, we ſhould deſcribe from the extremity *n* an arch at the opening of 120 or 125 fathoms; and if it cuts the ſide P O at the

point *l*, we ſhould raiſe thereon a flanc *l b* at diſcretion, then draw the line *b* P, as is ſeen in the figure.

If both ſides of the re-entering angle were too long to be within musket-ſhot, at the top of the angle we ſhould make a flat baſtion as in M, or elſe a platform as in D, if the flat baſtion ſhould take up too much of the length.

Laſtly, ſhould the re-entering angle happen to be between ſaillant angles that are too acute, as is the angle I, we ſhould ſhut it up in the place by drawing the interior ſide H L, which we ſhould fortify as we have done the others.

As for acute angles, *i. e.* thoſe that are under 90 degrees, we ſhould fortify them in the following manner.

Suppoſe we had the irregular place A B C D E F to fortify, whoſe angle A is under 90 degrees, we ſhould firſt look for the exteriors of all the ſides belonging to the place, except of thoſe which form an acute angle; we ſhould then increaſe the angle A at leaſt to 90 degrees, which ſhould be done by adding on each ſide half of the degrees the angle wants; thus ſuppoſe the angle be 60 degrees, as it is here, we ſhould make the angle B A H of one ſide, and F A L, each of them 15 degrees, which would make 30 for the two, which added to 60, makes 90. We ſhould then give the lines A H, A L, a reaſonable length for an exterior ſide, *i. e.* 170 or 180 fathoms; and then, either theſe lines would end at the extremities of the other exterior ſides, or would go beyond them; if they ſhould end there, as the line A H does, we ſhould fortify them by allowing the perpendicular but an eighth part, becauſe the angle is but 90 degrees; and if thoſe lines paſs beyond the other exterior ſides, as the line A L does, which paſſes beyond the exterior ſide O P, we ſhould then put this exterior ſide from O to L, without troubling ourſelves whether

Fig. 27.

whether it be parallel to the inward one, or not, and afterwards fortify the ſides OL, LA, as uſual, giving the perpendicular of the ſide AL but an eighth part, that the flanked angle may be at leaſt 90 degrees.

Should the collateral ſides, by this means, become too ſhort, we muſt increaſe the angle, and inſtead of making it 90 degrees, make it 100, or 110, *&c.* which would make the flanked angle much better.

To fortify places ſituated upon a river, on the ſea, upon an eminence, &c. *and thoſe whoſe ancient boundaries are to be preſerved.*

WHAT we have hitherto ſaid in relation to long ſides, has nothing to do but with places where rivers paſs under the walls without going in. We are now to ſpeak of thoſe that have rivers running through them, *fig.* 26.

And firſt, it is to be obſerved, that the paſſage for the entrance and going out of a river muſt always be made in the middle of a curtin, that it may have the defence of two flancs.

If the river be narrow, an arch muſt be made in the curtin, that is ſhut by a double grate.

If it be as broad as the curtin is long, you muſt drive piles from one ſide to the other, leaving only a paſſage in the middle for boats, barges, or ſhips, which muſt be ſhut at night by a chain; and beſides, outworks may be made on each ſide to ſweep the river with ſhot croſs-ways, and hinder the enemy from approaching.

Indeed a whole curtin might be built upon a bridge, whoſe leſſer arches (which might ſerve for the paſſage of boats) ſhould in time of war be ſhut up by double iron grates, and the great one (which is for barges) ſhould be barred

barred by booms or chains; and if the river were navigable for ſhipping, it would be ſufficient to build the leſſer arches, with the curtin over them, and not the great one, that ſhips might come in with their maſts up. If the river is broader than the curtin ſhould be, ſo that the two baſtions that are on either ſide cannot, with musket-ſhot, mutually defend each other, a fort is to be built in the middle, and the curtins might be joined in the manner we juſt now mentioned, which would make on the river a long ſide of three baſtions. It would be proper at the ſame time to fortify the ſides of the town that are upon the river, ſo that the two parts might be like two different towns, that in caſe the enemy ſhould get through the defences, that are either at the coming-in or at the going-out of the river, he might not be able to advance without finding himſelf between two fires.

Maritime places are fortified on the land-ſide as others are; and on the ſea-ſide ramparts are made, on which cavaliers are raiſed at proper diſtances from each other, in order to keep the enemy as far off as poſſible; and little forts muſt be built on every place of the coaſt, from whence a firing towards the ſea will be of any ſervice.

The entrance into harbours is fortified juſt as that into rivers is; but it is better to flank it with a good citadel on either ſide, becauſe the enemy can appear at ſea with a larger number of ſhips, and in a larger front than upon a river.

As for places that are upon high and ſteep rocks, in order to fortify them, we muſt conſider how their figure is ſituated. without minding whether the ſides be too long or too ſhort, or the angles acute or re-entering; becauſe in this caſe the miner cannot work againſt you. The rampart is cut out in a rock, at the top of which a parapet of earth is raiſed, taking

taking care withal to leave nothing in the way to obſtruct our view on all ſides. The foſsè is not very deep, by reaſon of the great expence of digging it; but it is made very broad, that there may be room for good defences, and all neceſſary out-works are added to ſcour the foot of the rock. But here care muſt be taken to have the communications, under covert, to retreat by in caſe you are obliged to quit them; becauſe it would be impoſſible for thoſe that would go up to the place to eſcape the enemy's ſhot, who could otherwiſe diſcover them from head to foot.

When a place is upon the ſide of a hill, you muſt of neceſſity occupy all that is above it, either by incloſing it within the walls, or by out-works; or laſtly, by building a good citadel to avoid being commanded; and as the enemy may make himſelf maſter of theſe poſts, you muſt provide againſt this in time by raiſing parapets and traverſes in all the parts that may be annoyed, as we have directed elſewhere. The reſt is fortified as uſual, by making out-works, as we have juſt now ſaid, to ſcour the foot of the hill.

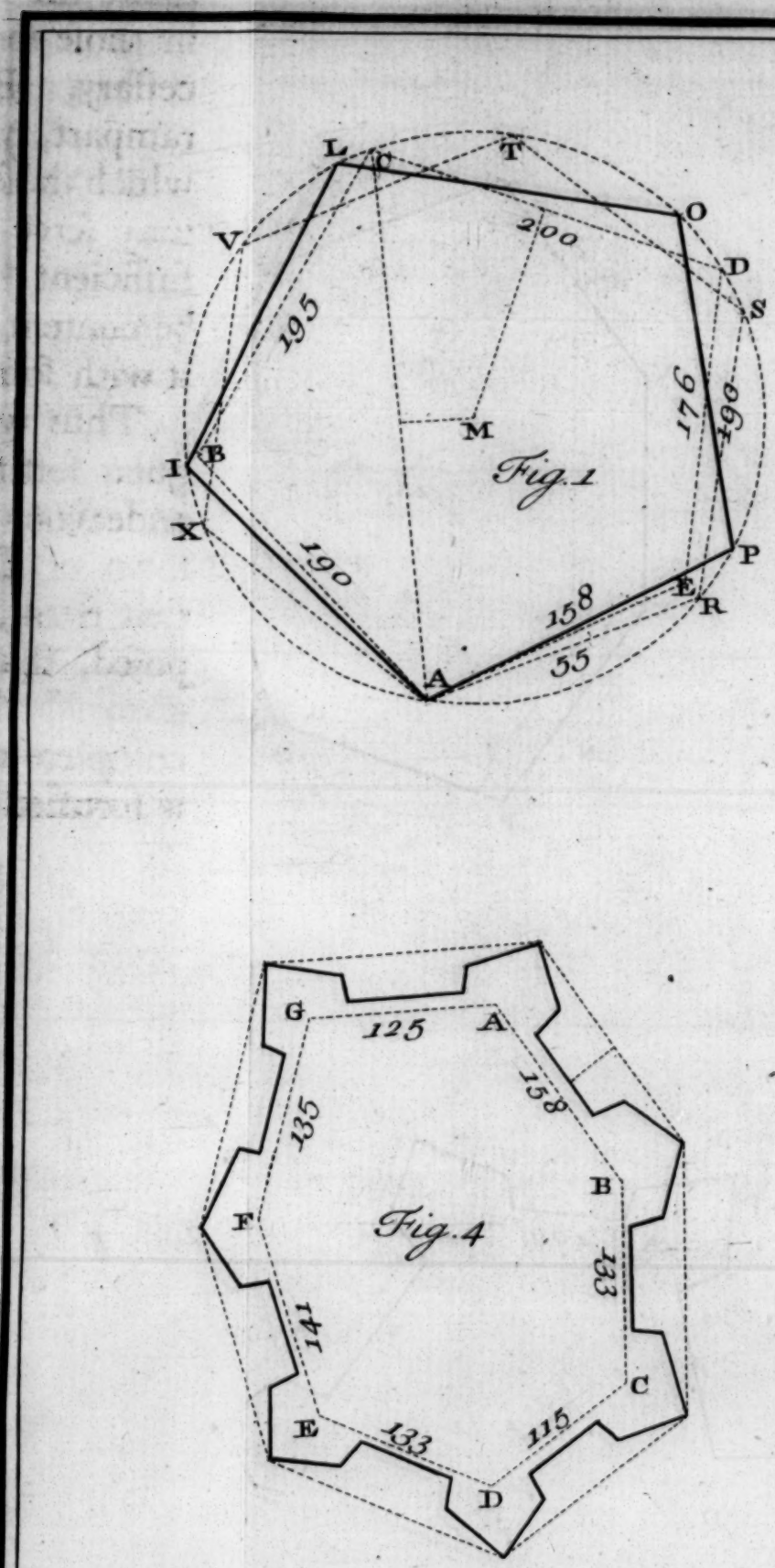
Places every way ſurrounded with marſhes have much the ſame advantages as thoſe have that are ſituated upon ſteep rocks; that is to ſay, that in this caſe ſides either too long or too ſhort, and angles either acute or re-entering, are here no great defects, becauſe it is not poſſible to approach them; but were it poſſible to drain the marſhes, we muſt then take care of them, and build new forts in thoſe places where the enemy might attempt to make a drain.

As for places whoſe ancient boundaries are to be preſerved, you muſt terraſs their walls, if they are ſtrong enough to bear a rampart; correct the places that are defective; add good baſtions to them; and, ſhould the curtins happen to have round or ſquare towers, fill them full of

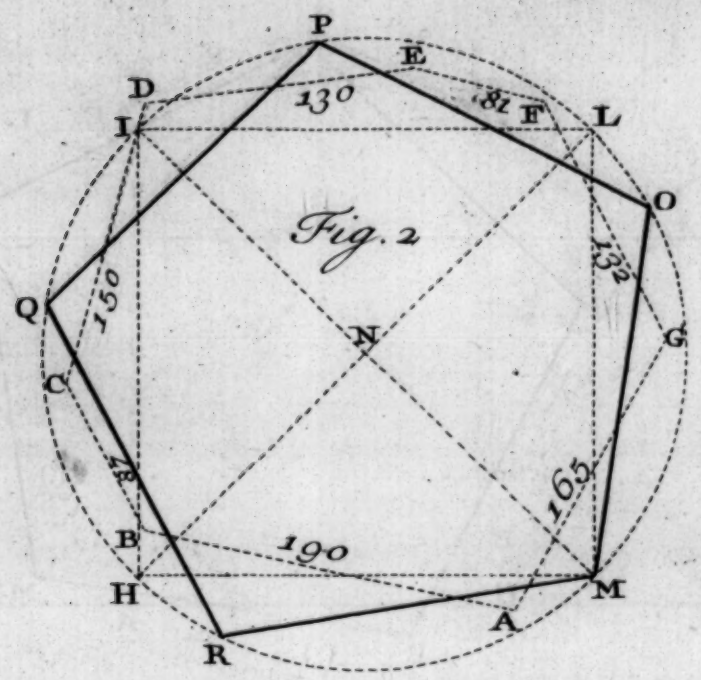
of earth, to make uſe of them as cavaliers. You muſt then make the foſsè ſtill deeper, which commonly is too ſmall in thoſe ſort of places, adding whatever out-works are neceſſary. But if the walls are not ſtrong enough to bear a rampart, you muſt make ſome new fortifications, within which thoſe walls may be incloſed, that in time of need they may ſerve for intrenchments, and ſhould there not be time ſufficient to make a new circuit of fortifications, you muſt be content to enlarge the foſsès of the old one, and fortify it with ſome good out-works.

Thus we have examined all the different caſes of irregular fortification, and would recommend to our readers to endeavour to get in their poſſeſſion an exact plan of the town of *Luxemburgh*; in fortifying of which, the parts that flank, and thoſe that are flanked, are ſo artfully diſpoſed, that the irregularity of the works does by no means diminiſh the ſtrength of the place, which may ſerve as a complete model of its kind, ſince it appears that the whole is fortified according to the beſt maxims of the art.

End of the Firſt Volume.



The Six Plates Numbers 42 to 47 are to be placed at the end of the



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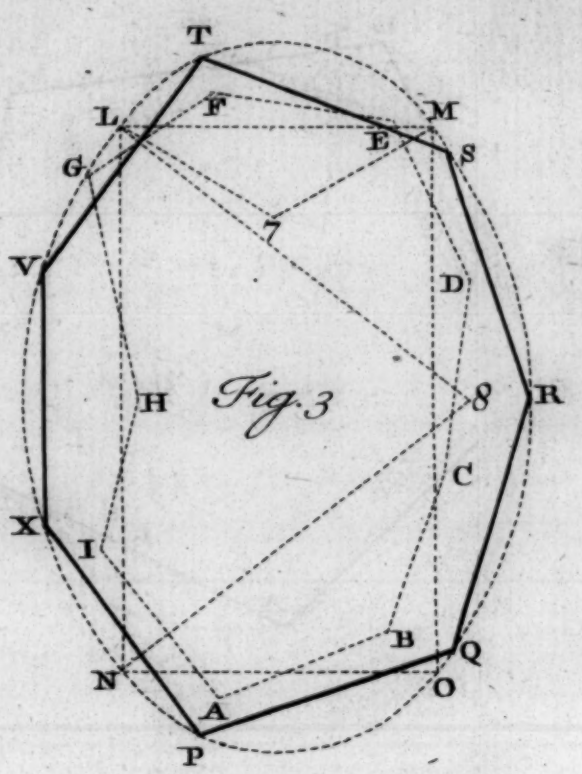

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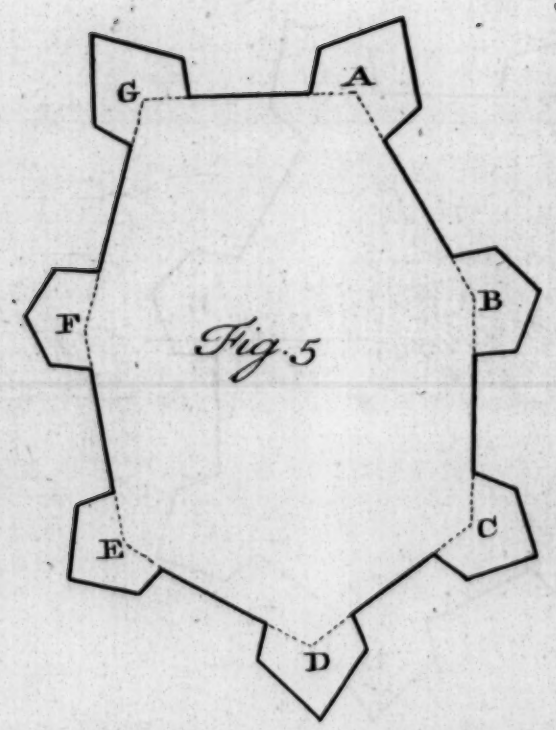

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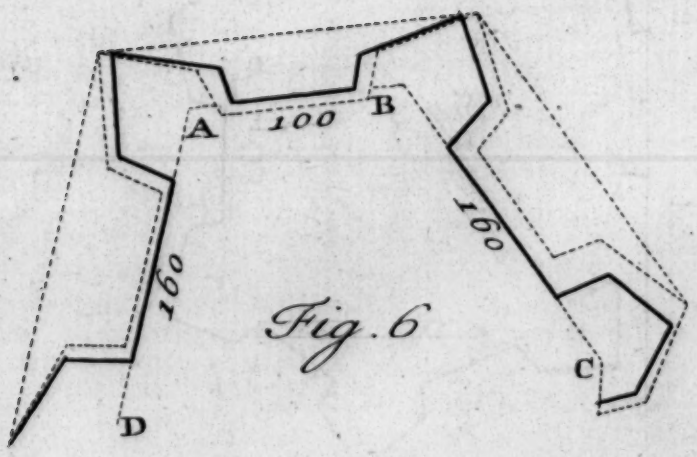

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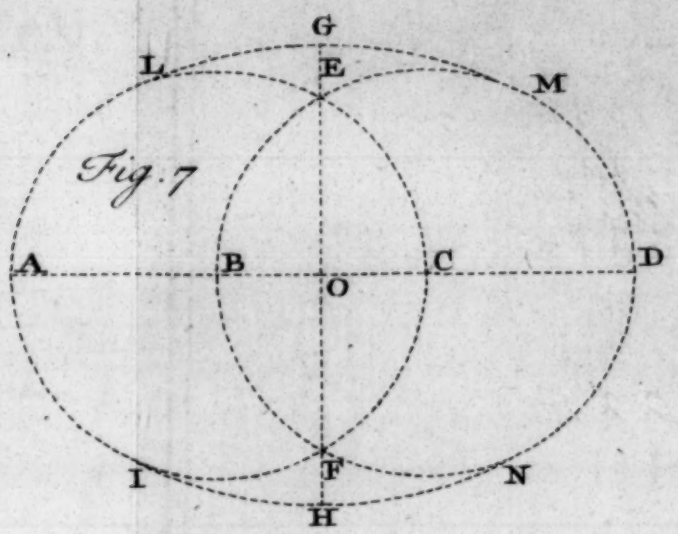
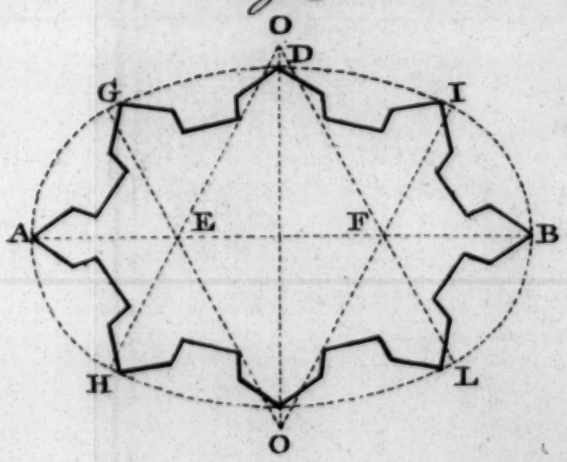
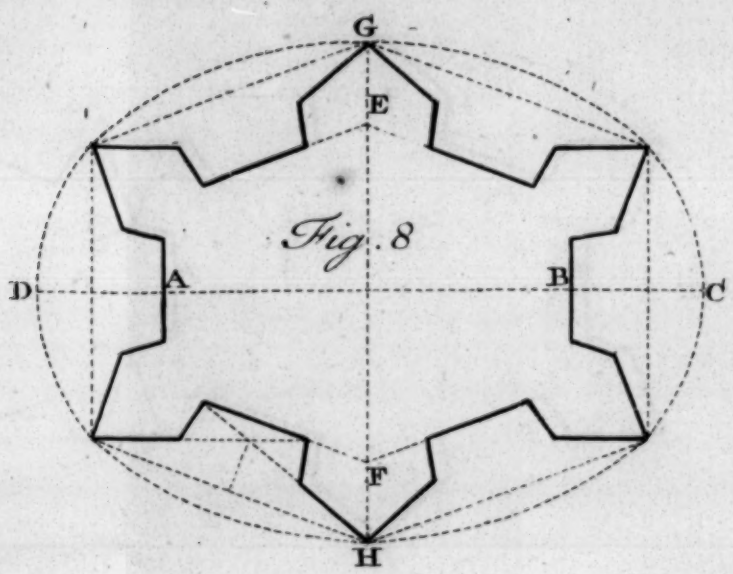


Fig. 7

Fig. 9





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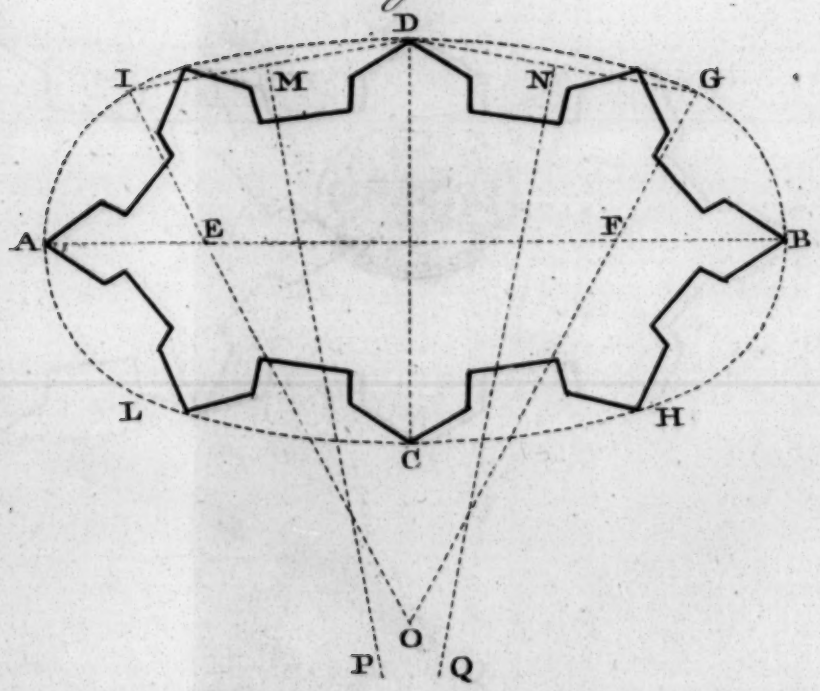

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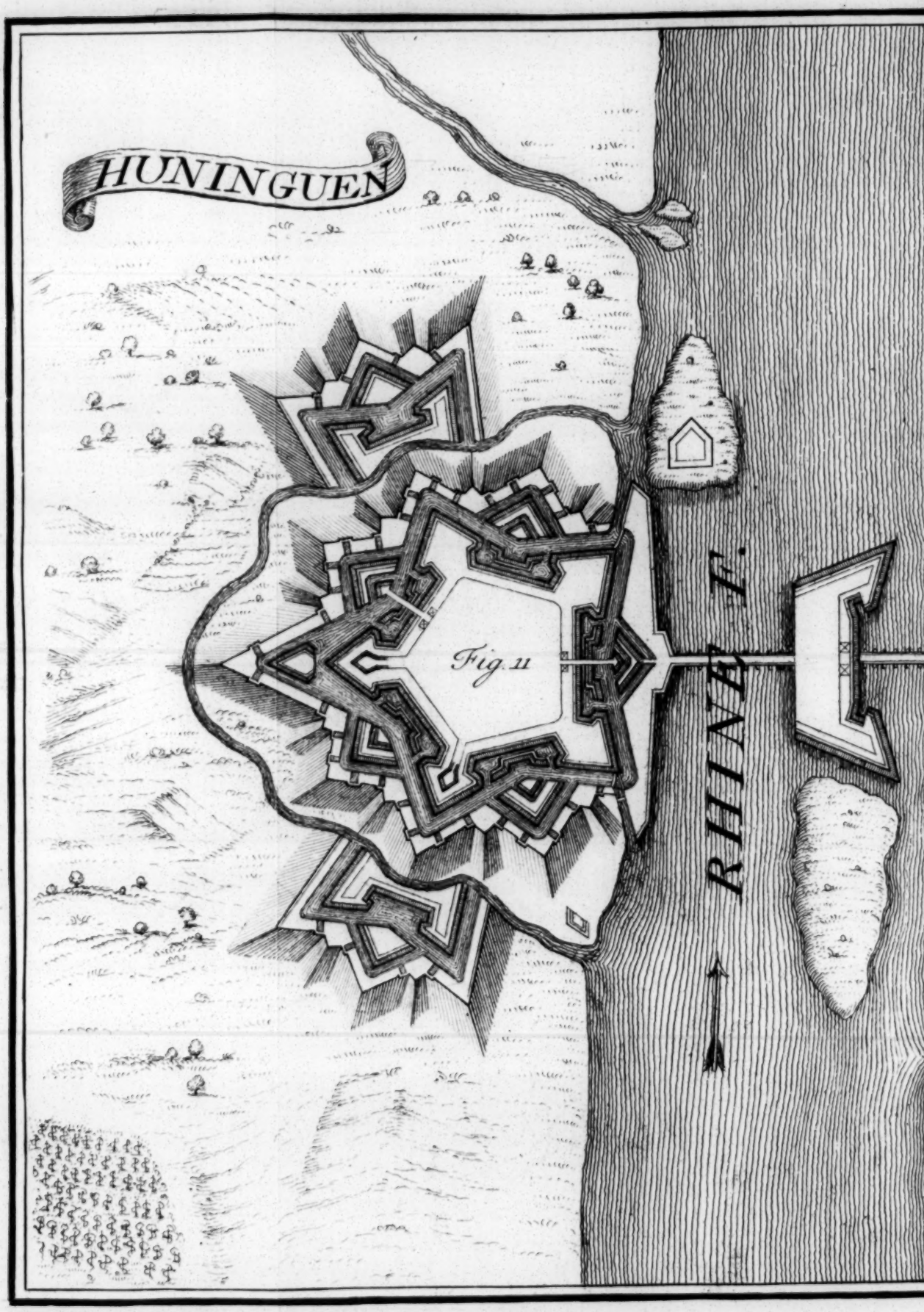

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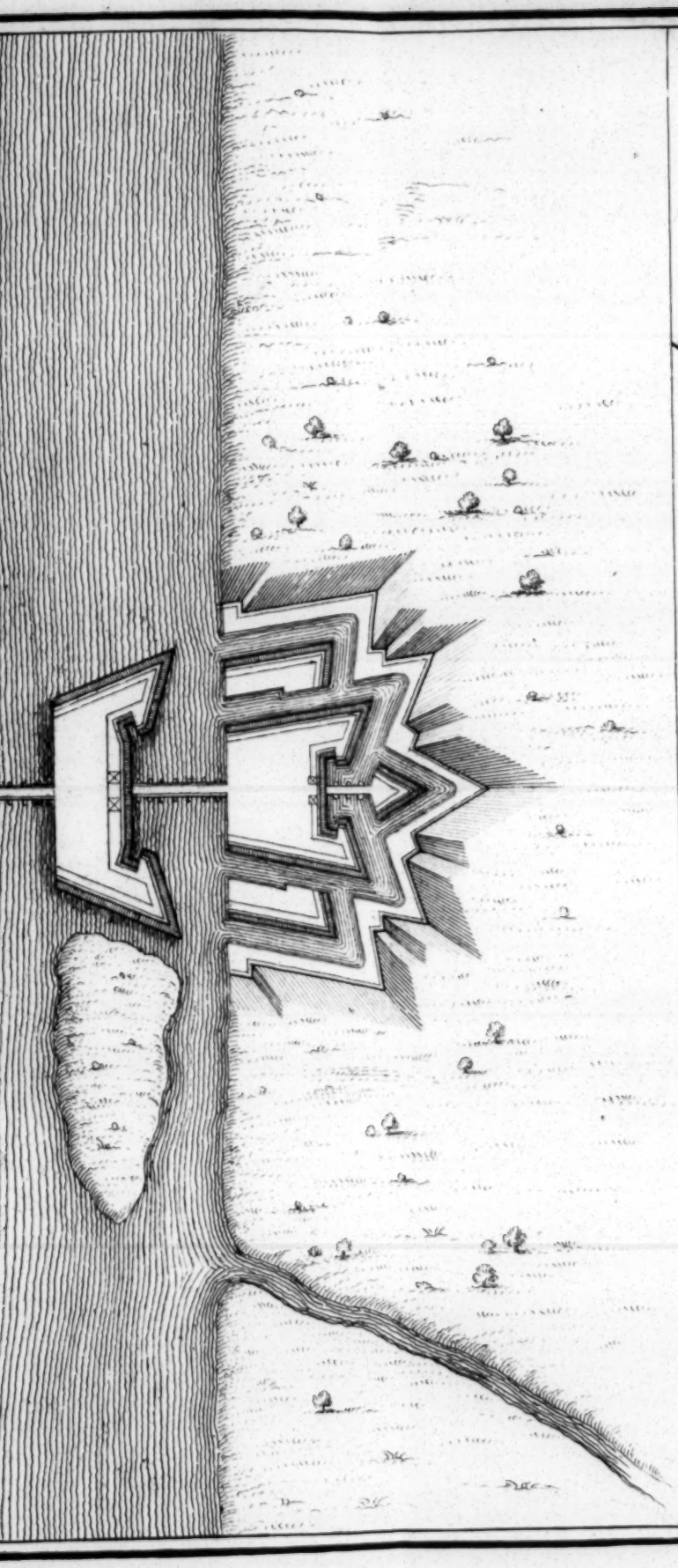


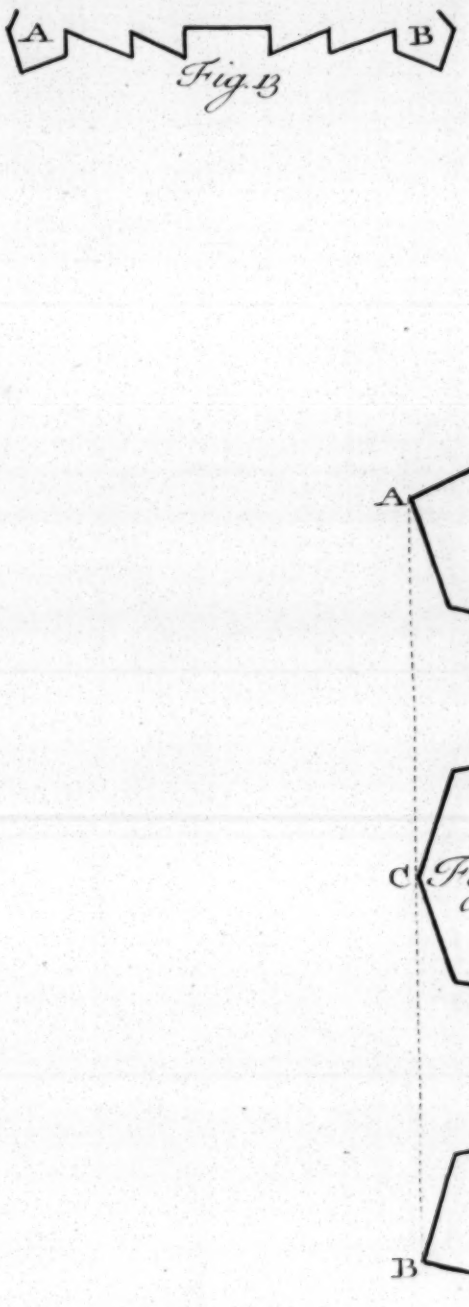


Fig. 12

Fig. 14

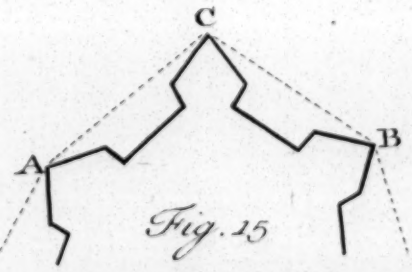
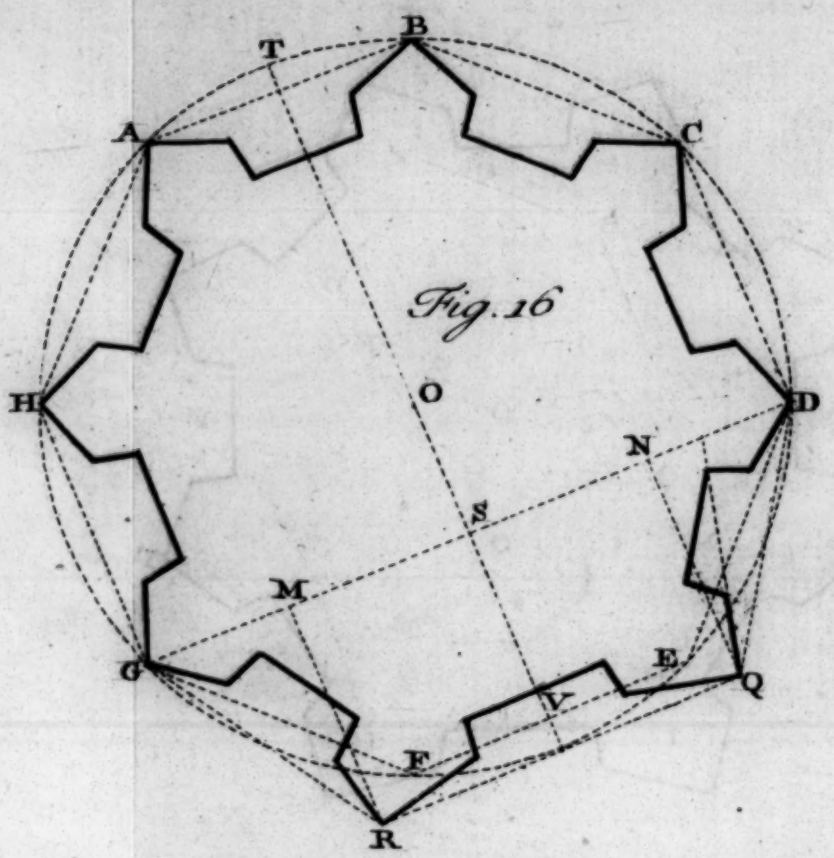


Fig. 15

Fig. 13



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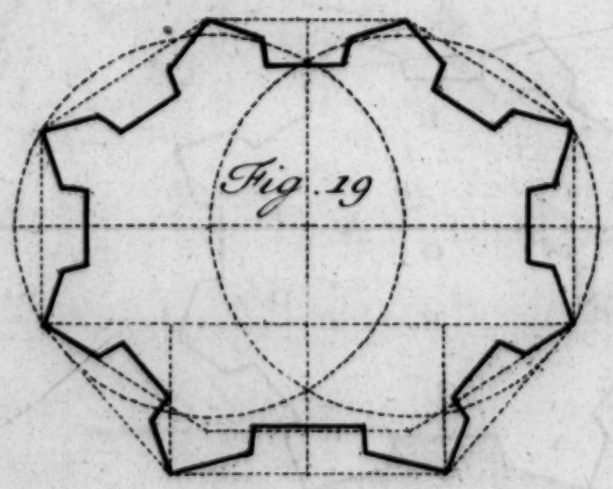

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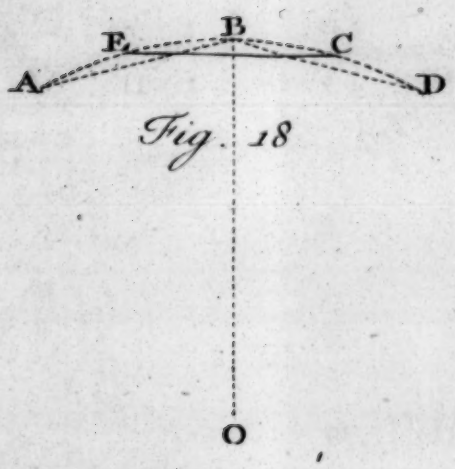

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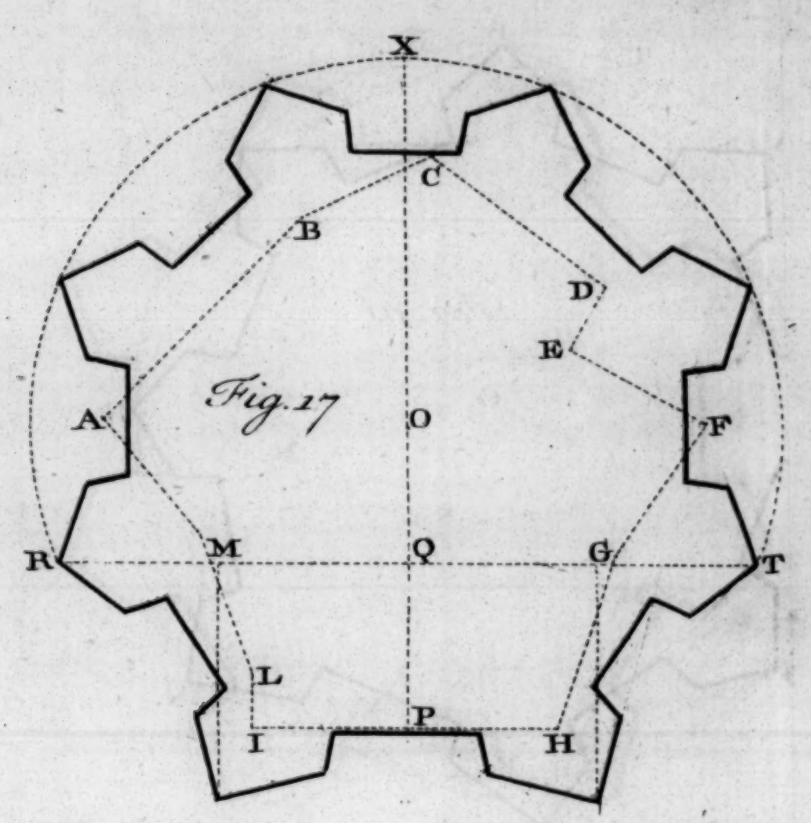

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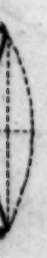

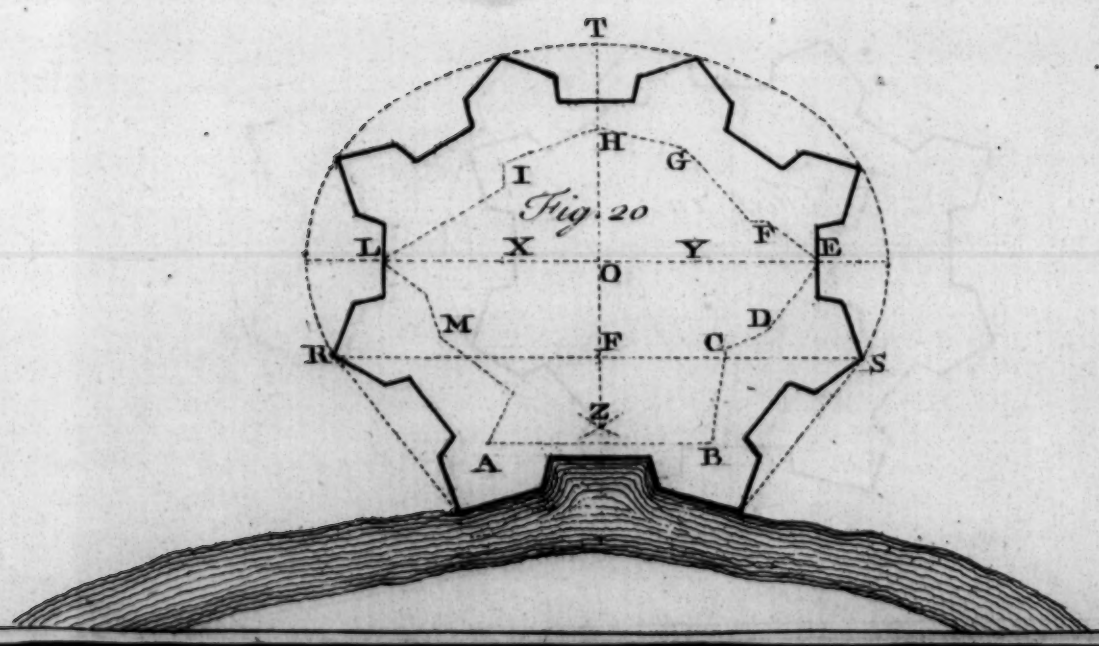

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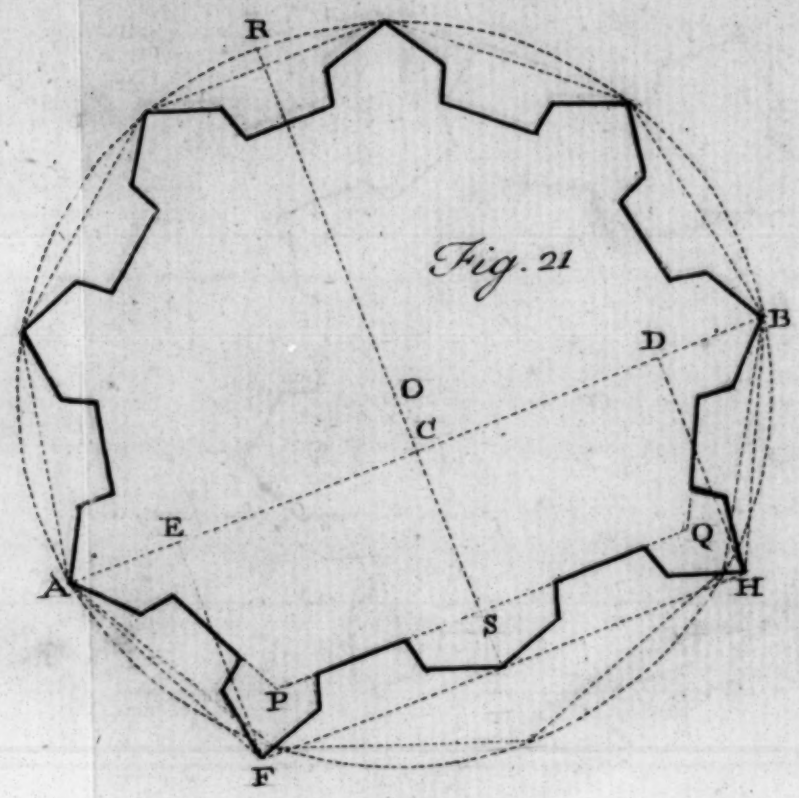

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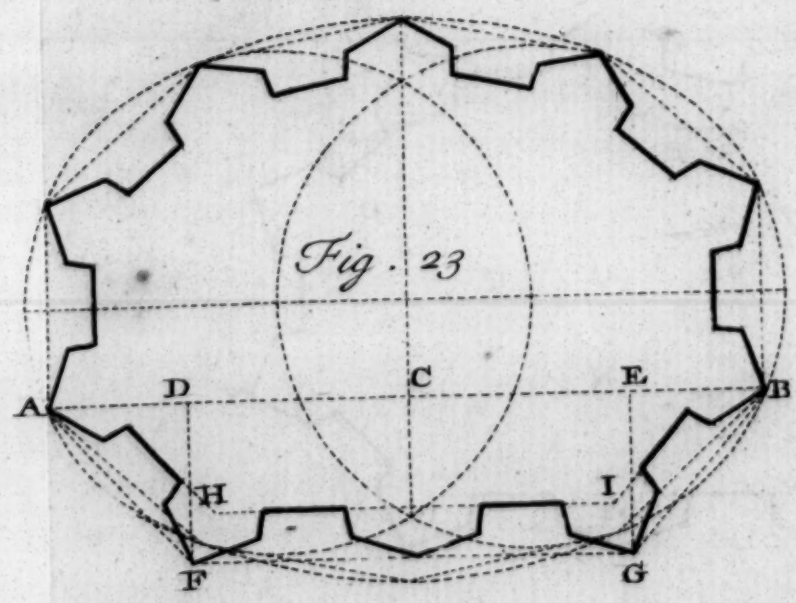

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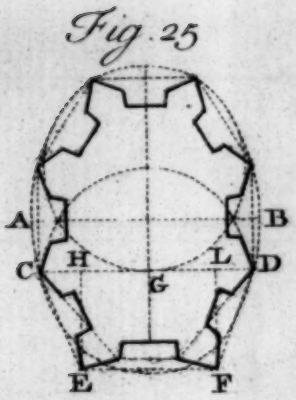

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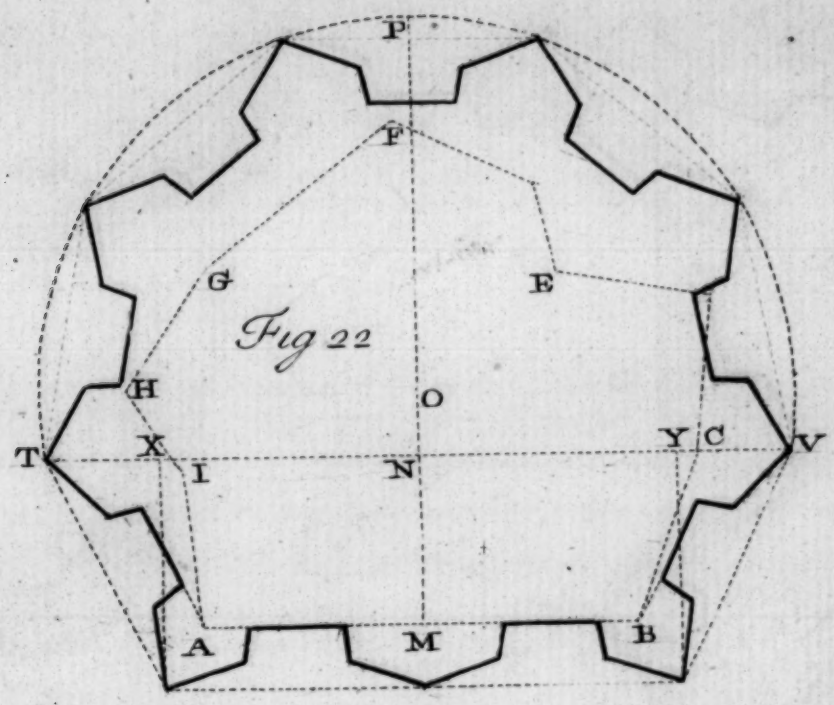

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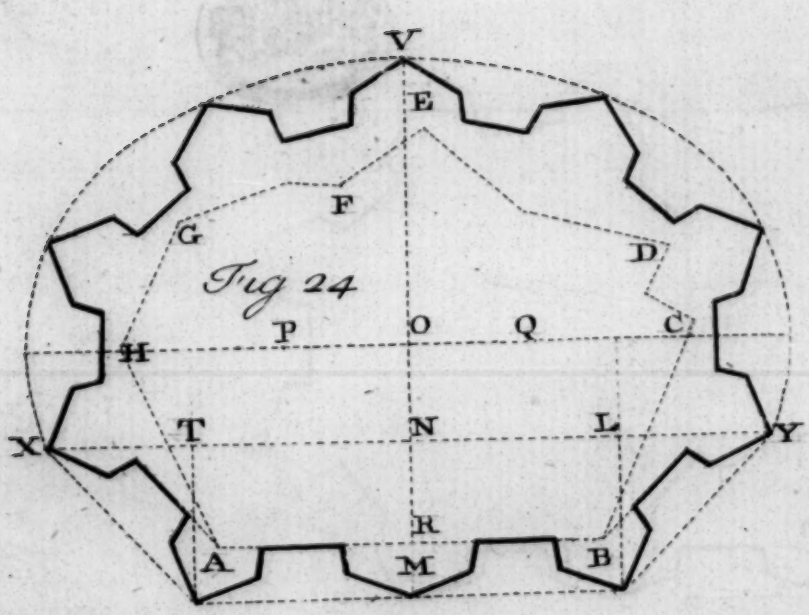

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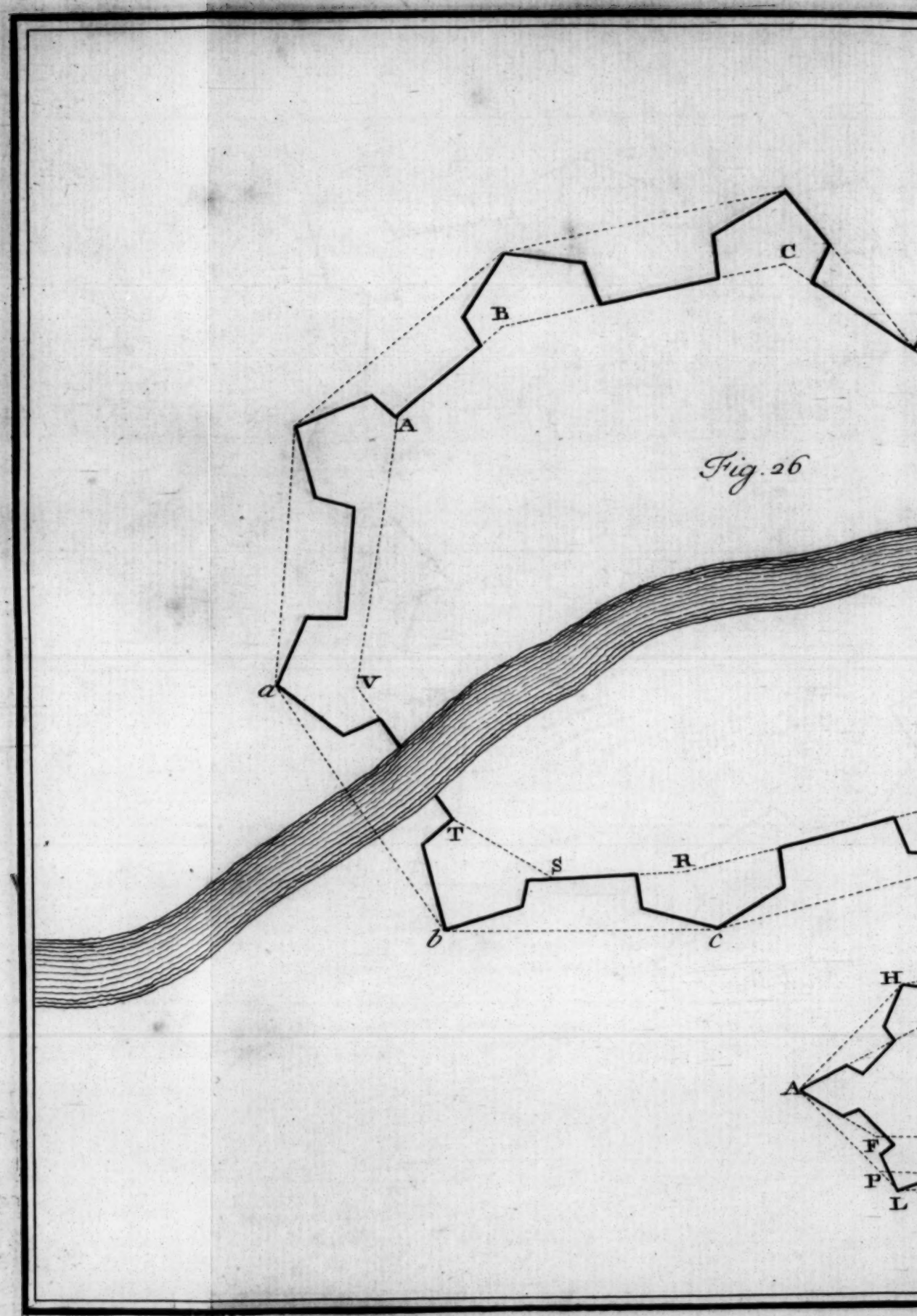

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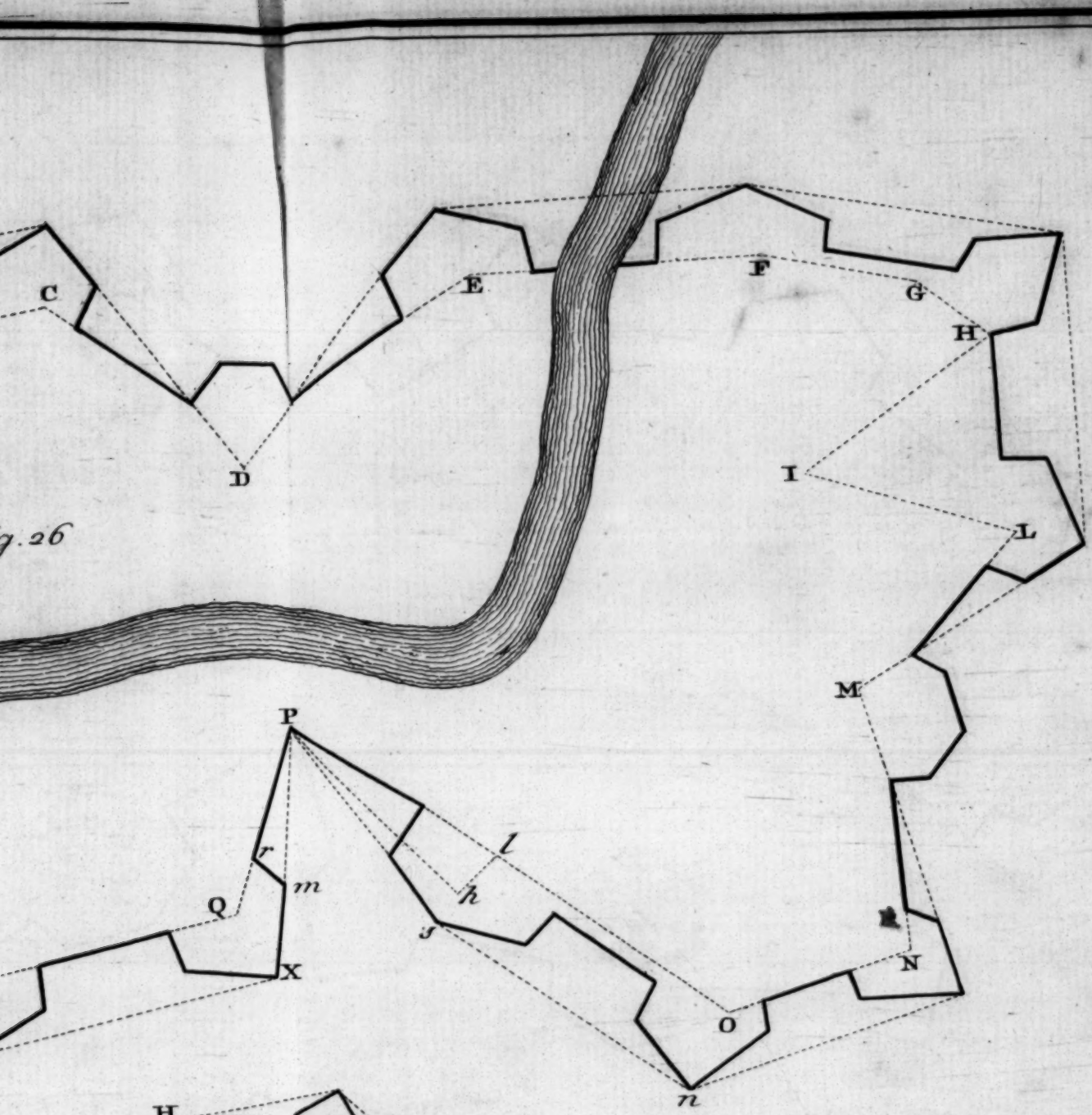

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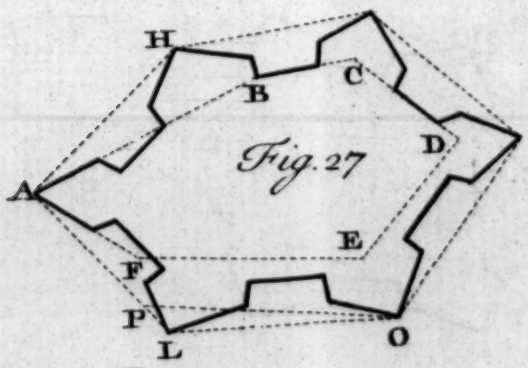
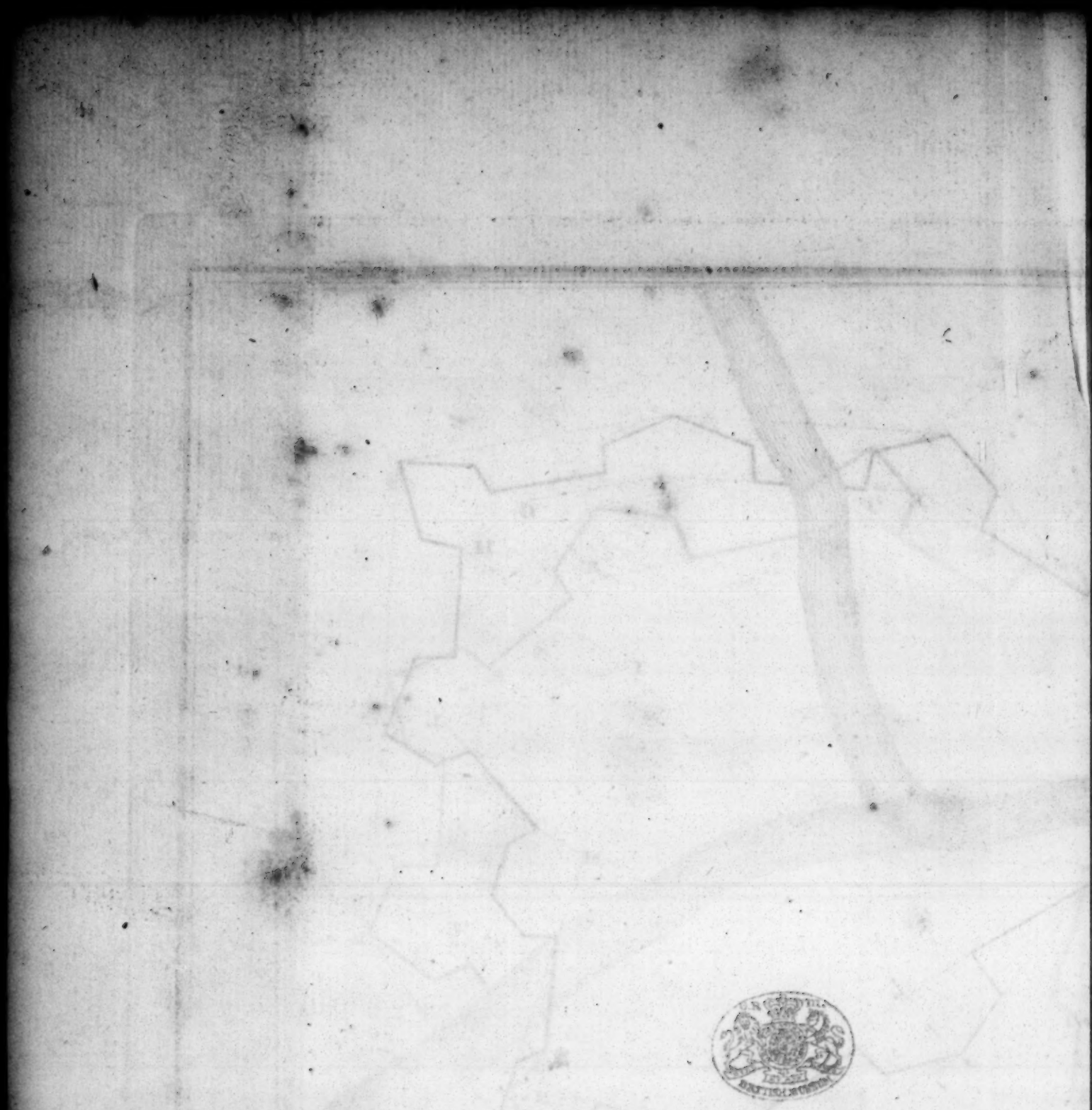
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